METAL Progress

Metal Progress

September 1959 .... Volume 76, No. 3

Cover: Another winner (second prize) in A.S.M.'s annual competition at Cleveland Institute of Art is this month's design by Harvey Klineman based on alchemical symbols.

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**The coding symbols refer to the ASM-SLA Metallurgical Literature Classification, International (Second) Edition, 1958*

Centrifugally cast Thermalloy tube burst at 77,500 psi

Wrought tube burst at 70,100 psi

Burst tests prove 7,400 psi superiority of centrifugally cast Thermalloy® tubes

Hydrostatic pressure tests by Electro-Alloys established the rupture of a centrifugally cast Thermalloy tube section at 77,500 psi. Under the same conditions, wrought tubes of comparable section and analysis burst at 70,100 psi. These tests were conducted at room temperatures. Tensile tests show this strength margin increases substantially at the higher operating temperatures (1200°-2200° F). The Thermalloy tube was tested *as cast* —without machining the inside or outside diameter.

Thermalloy is a group of heat-resistant alloys developed for use in the range of 1200°-2200° F. The greater strength of the Thermalloy centrifugally cast tubes makes them ideal for use in radiant tubes, retorts, rolls or other heat-resistant designs employing tubes. For further data, call your representative, or write Electro-Alloys Division, 1016 Taylor St., Elyria, Ohio.

AMERICAN Brake Shoe COMPANY

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Metal Progress

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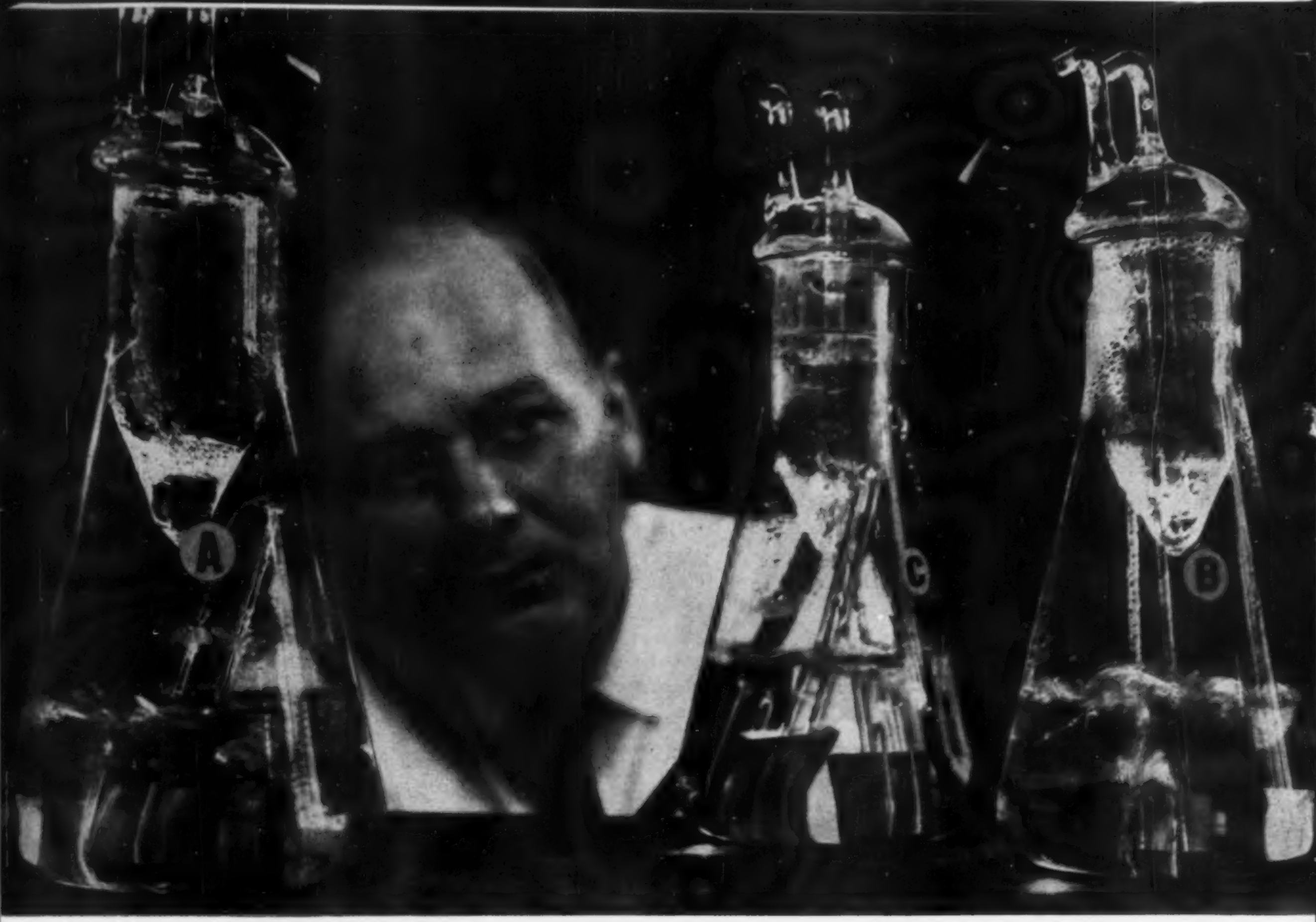

Here, boiling nitric acid is used to evaluate the corrosion resistance of Jessop stainless steel plate.

"How Jessop Tests Stainless Steel in Boiling Nitric Acid"

L. W. Cooper, Chief Metallurgist

"From experience, our customers know this is a fact: Specify Jessop for specialty steels . . . and then relax! Of the many reasons *why* this is true, here's one . . .

"In evaluating corrosion resistance, one of the procedures we use is the ASTM boiling nitric acid test. Standard and simple? Yes. But expert *evaluation* is of great importance to the customer. That's why, at Jessop, a top metallurgist closely supervises each of the five 48-hour test periods.

"*Overly cautious?* Because we're overly cautious in *every* phase of steel production and quality control, Jessop has earned the reputation for producing specialty steels tailor-made to the most exacting specs— *Specify Jessop . . . and then relax!*"

Checking the grain size of tool steel, this Jessop metallurgist uses a microscope with a camera attachment. VMA 6787

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Jessop Steel International Corporation
Steel Warehousing Corporation, Chicago

JESSOP STEEL COMPANY
Washington, Pennsylvania

Stainless, alloy, tool, cast-to-shape, clad, and forging steels, ground flat stock and other specialty steels

Press Breaks...

Press Breaks this month may well be a series of items taken from the Editor-in-Chief's note book and letters to staff members during the first part of his recent European trip. This was strictly a vacation, but you know the adage about the busman's holiday. Mr. Thum evidently carries with him a metallurgical viewpoint:

Small World Department

While standing on the steps of the Vatican Museum who should appear but Dick Wiley, past chairman of the Washington Chapter. He and his wife and daughter were on a tour with 60 or 70 others, a group organized by Naval Ordnance Research. They were on their own that day, else we might have had an overseas chapter meeting on the spot; it would not have disturbed anybody, since there were at least 10,000 tourists in the Sistine Chapel that morning.

At the Cathedral in Pisa was a handsome policeman with an armband lettered "English", the very spit and image of a good ASM'er and equally as suave and helpful as his double Peter Kosting, long at Watertown Arsenal but now division director at the Office of Ordnance Research (U. S. Army) at Durham, N. C. The two are not related.

Metallurgical Notes – Cuprum Division

There was evidently a shortage of metal in Rome in 1670 when the enormous bronze canopy was erected above the papal altar at St. Peter's. The heavy metal panels lining the great dome of the Pantheon were removed and re-cast – possibly defensible because the Pantheon was originally a pagan temple, rebuilt by the Emperor Hadrian in the 2nd century A.D. The guide didn't know where Hadrian stole the bronze in the first place.

"The Gates of Paradise" are, fittingly enough, of bronze. So Michelangelo characterized the east doors to the ancient Baptistry, just in front of the Cathedral in Florence. Each door has five scenes from the old testament, designed by Lorenzo Ghiberti, an eminent goldsmith of the mid-15th century. One might guess that these ten elements were cast separately and fitted into a main frame which in turn was bolted to a stout oak skeleton, although there is only the slightest suggestion here and there of any joint. A similar bronze panel, on exhibit in one of the many museums, was evidently a slush casting, although the coring for undercuts must have been intricate in the extreme. The fineness of the surfaces, the delicate tracery in the backgrounds, and the paper-thin leaves on the decorative foliage on the Baptistry doors indicate that an enormous amount of hand work was necessary to finish each casting. (The contemporary bronze doors at the Cathedral in Pisa were made in many small pieces. Not only the frame but also the panels themselves show clearly many joints and pins.)

I must find someone who knows something about these exquisite techniques and get him to write an article for *Metal Progress*.

Hands-Across-the-Sea Division

Prominent posters observed in Naples had this big headline:

Sciopero
dei Metallurgici!

The "dei" led me to hope that the Italians had at long last deified metallurgists, but a friend interpreted it to mean a call for a mass-meeting of striking steelworkers. Messrs. McDonald of the Steelworkers' Union and Cooper of the American steelmaking industry might take note that they have not been alone in their economic troubles! (*Continued on p.* 6)

Press Breaks . . .

Metallurgical Note – Plumbum Division

The small lead pipes which supplied some citizens of Herculaneum with water are still in operating condition. This city was engulfed by a mudslide from the Vesuvius eruption of 79 A.D. The pipe was made of lead sheet (possibly cast on a flat stone slab) trimmed, bent and soldered longitudinally. Extrusion is modern; it had to wait the construction of powerful hydraulic machinery.

Metallurgical Note – Argentum Division

In the treasure room of the Duomo, the Cathedral at Florence, is a silver altar made during two centuries by the best of the city's silversmiths (none better anywhere, anytime). Fortunately it can be examined closely. It is made up of many deeply embossed panels of silver sheet, perhaps 16 in. square, representing various scenes in the life of John the Baptist, the city's patron saint. A photograph of one of these panels is reproduced; it will be seen that each of them is fitted between highly ornamental mullions and pilasters, the latter containing niches with small statues. Literally thousands of such items, each one a gem, are soldered and pinned together and to the underlying frame, joined so closely as almost to defy detection.

Note on Motor Cars

Up Italy, from Naples to Rome to Florence to Riviera there was not a single automobile graveyard to be seen, even though the roads were crowded with everything from motor scooters to trucks with double trailers. From Cannes to Grenoble to Vezelay in France, billboards appeared and two small auto dumps were counted. You pass (and are passed by) many vintage Renaults and Citroens with boxy bodies like the Model T Ford. Undoubtedly autos are better cared for than in America – even the trucks are clean and have good paint jobs.

Rail Transportation Note

Judging from the dilapidated condition of the station buildings and railway right-of-way, the branch lines in Burgundy are suffering as much from automobile and truck competition as they are in the United States. The antiquated Pullman cars (next step above First Class) such as the famed "Golden Arrow", Paris to London, suggest one reason for this. However, the Rome-to-Milan express leaves nothing to be desired in speed and comfort.

Detail of the Silver Altar: John the Baptist in the Desert

Metal Progress

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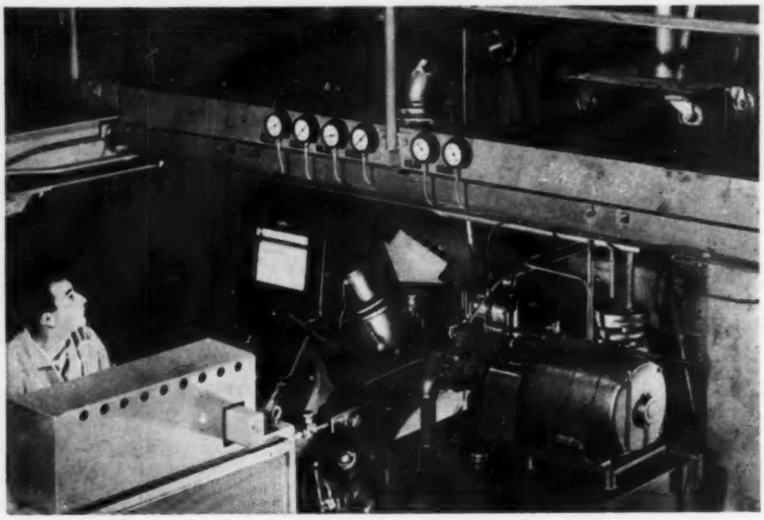
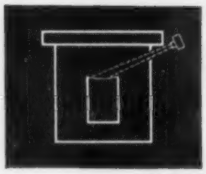


CONTINUOUS MELT RECORD AT 3000°F with the *Radiamatic* unit (arrow) attached to a Stokes semi-continuous vacuum furnace at Allegheny Ludlum Steel Corporation, Watervliet (N.Y.) Works. Honeywell engineers worked with Allegheny-Ludlum to provide a constant record of vacuum furnace temperature—without calibrating rheostats or other complicated adjustments.

Honeywell has the tools to solve your high temperature measurement problems



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For measuring temperatures to 7000°F.

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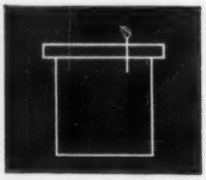

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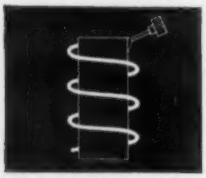
For sensing temperatures in the area of 4000°F.

New experimental Honeywell thermocouple materials like Rhenium-Molybdenum and Rhenium-Tungsten measure temperatures as high as 4000°F. Great diversity of elements and accessories permits you to select the thermocouple which fits your application exactly.



SAPPHIRE RODS

For measuring temperatures to 3600°F.

Sapphire rods, used as lenses in *Radiamatic* pyrometers, provide accurate high-temperature measurement where such measurement previously could not be made by conventional means . . . can "sight" on a target as small as ⅛".

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GROBET FILE CO. OF AMERICA, INC., uses 3 across the line electric furnaces for clean, uniform heat treatment of chisel cut and rotary files. Operation is critical as cutting edges must be protected during hardening. Equipment consists of 3 Model Y furnaces with the Sentry Diamond Block method of atmospheric control, manufactured by the Sentry Company, Foxboro, Mass. These and all other Sentry furnaces use GLOBAR elements "across-the-line", exclusively.

OPERATE
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Compact, simply controlled electric furnaces, connected "across-the-line" on 115 or 230-volt power distribution systems, offer new opportunities for economical heat treatment under favorable conditions in the medium temperature range. Higher temperatures are possible for certain operations.

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New advance increases ECONOMIC ADVANTAGES OF ELECTRIC HEAT

Electric heating is meeting the growing demand of industry today. The adaptability, versatility and dependability of long-life silicon carbide elements, the ease of replacement without a complete shutdown, and minimum maintenance are vitally important to the operator.

Electric heating is economically attractive for a wide range of processing operations. Simple, low-cost installations, without expensive transformers, are easily controlled by an automatic pyrometer and magnetic contactor up to 2000° F, and favorable operating requirements may permit higher temperatures. Applications should be carefully evaluated and individually engineered. Electric heating efficiency is high, you don't pay for Btu's that go up the stack. Exhaust and fuel storage facilities are unnecessary. It is clean, safe and quiet with no fire or explosion hazard. Compact GLOBAR equipped furnaces may be located anywhere in a production line. Product quality is improved and rejects are reduced.

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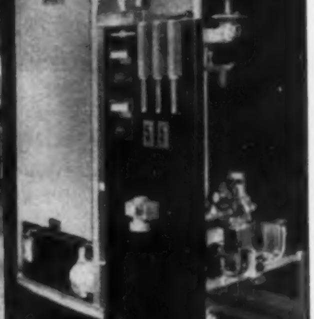
Typical applications for GLOBAR Delta elements include Ceramic firing, heat treatment, forging, sintering, brazing, annealing, melting, assaying, roasting and laboratory control and testing.

WIRE ANNEALING FURNACES at Electric Wire Company of Northampton, Mass., use GLOBAR elements across a 220 volt line and operate at 1800° to 2250° F. GLOBAR silicon carbide elements installed over 18 months ago are still in use.



LATEST TYPE "IGL" Hayes Protective Atmosphere Generator, uses 12 GLOBAR Delta elements on 230-volt supply. Customers report only slight increase in resistance after extended service.

Find out how your operation can profit by using GLOBAR Delta silicon carbide heating elements. Your furnace builder can supply you with full details. The Carborundum Company, Refractories Division, Globar Plant, Dept. MP99, Niagara Falls, New York.

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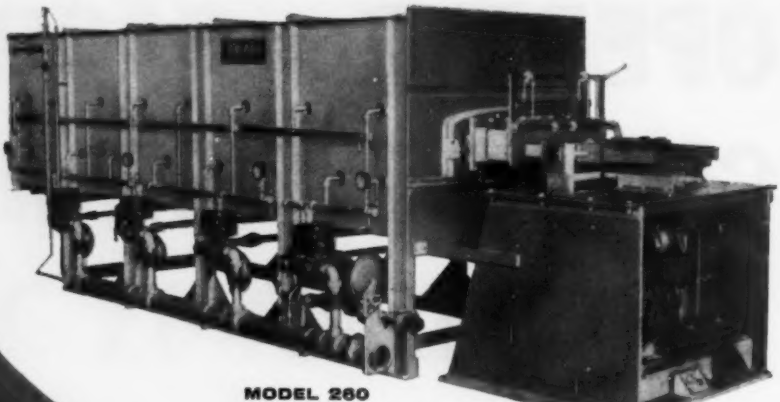
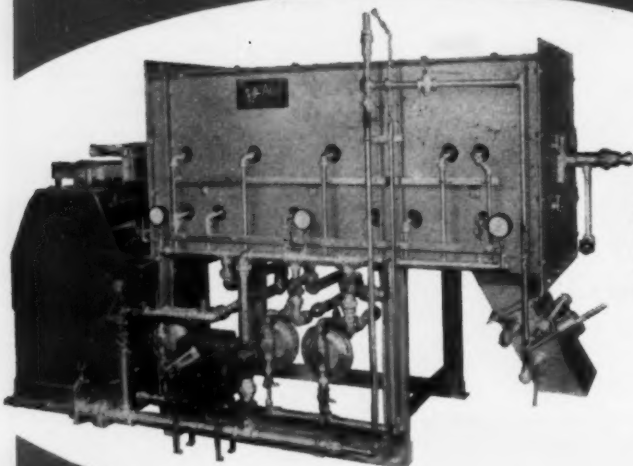


MODEL 260
Shaker Hearth Furnace, with a production capacity of 800 lbs. per hour.



MODEL 238-A
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VERSATILE Complete atmosphere control for heat treating from pen points to forgings, *IN THE SAME FURNACE.*

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For this reason, technicians at Stanford University use Silvaloy 45 and Deoxo Flux for their reliable quality and consistent performance.

Silvaloy brazing alloys and fluxes are helping to speed production, lower costs and improve brazing results in many fields. Call your nearest Silvaloy distributor for information or technical assistance.

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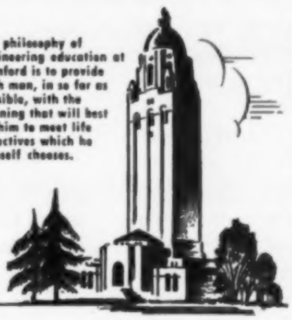

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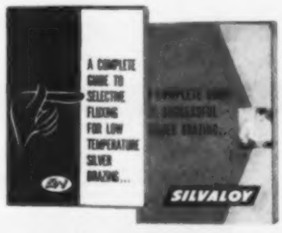
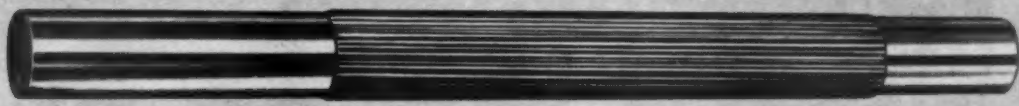


Two complete reference manuals for low-temperature silver brazing and fluxing are available upon request. Send for either one or both. ★ ★ ★ ★ ★ ★ ★



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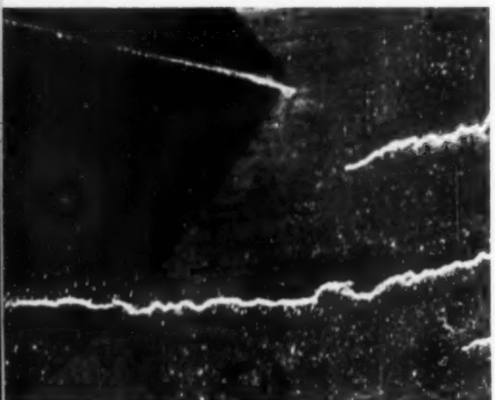
most used test for magnetic metals



By far the most common crackfinders used on magnetic metals for critical service, Magnaflux and Magnaglo use magnetic particles and controlled magnetic fields to find all cracks, inclusions or other defects at or close to the surface. Sensitivity is adustable to find either defects as small as a few millionths of an inch or only the grosser ones.

Magnaflux and Magnaglo will find some types of defects that other tests will overlook. They mark defects right on the part. Magnaglo uses fluorescent materials and high intensity black light. Speed of testing is governed solely by production needs, on parts weighing from fractions of ounces to many tons. Fully automatic processing is often provided with the inspector merely "monitoring" parts as they pass through the machine. Cost per part tested is usually even less than for visual inspection alone, and many times more accurate.

Inspection with Magnaglo shows otherwise invisible fatigue cracks in forged part.

ZYGLO® and ZYGLO-PENTREX®

most used test for nonmagnetic materials - fluorescent penetrant, black light.

Zyglo and Zyglo-Pentrex use capillary forces to find cracks—or any other defects open to the surface—in such materials as aluminum, titanium, magnesium, plastics, glass and others. They may be used successfully on rough surfaces where ordinary visual inspection is hard or impossible. All defects are marked directly on the part. Recent improvements have increased maximum sensitivity beyond that of *any other method* in finding and defining certain defects. Near-absolute reliability is assured in leak tests. Adjustable sensitivity for any requirement prevents "over-inspection" and needless rejection. Engineered systems can be full automated.

At any test rate, cost is low; on volume production cost per piece is negligible.

Zyglo reveals and marks serious cracks in stainless steel part.

Magnatest FM-110 Transistorized Conductivity Meter, as used to sort copper billets according to conductivity, prior to machining.

(Photo courtesy Ampco Metal, Inc., Milwaukee)

Magnatest FW-400 Rod, Tube and Wire Testing Unit as set up for production inspection of copper tubing at mill speeds.

(Photo courtesy of Wolverine Tube Co., Detroit)

SONIZON®

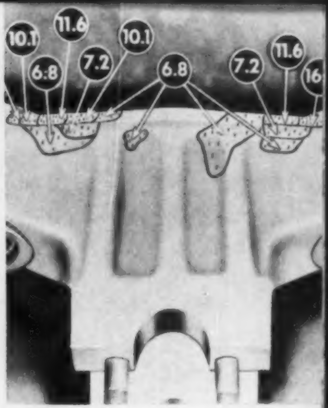
Ultrasonic instruments use sound you cannot hear to measure thicknesses you cannot see —or to find hidden defects.

Sonizon SO-200 portable, direct-reading type instrument used here to measure pipe wall thickness.

Sometimes called "a micrometer with only one arm". Magnaflux Sonizon measures thicknesses from one side as quickly as a crystal probe can be moved over the surface. Sonizon instantly detects thin (or corroded) spots in tank walls; in cast, formed, welded or ground shapes; it also reveals defects deep below the surface including laminations and lack of bond. Instruments are available in a unique portable direct reading type (see illustration) and the oscilloscope type.

STRESSCOAT®

Spray-on brittle coating saves time and cost. Gives overall stress analysis.



Stresscoat applied to prototype aluminum truck beam saddle shows operating stresses and concentration points.

Stresscoat determines stress concentration and measures values in simple or complex shapes, in static or dynamic testing. It predicts where parts would fail, so that they can be correctly designed not to fail in service. This makes possible better products that are lighter, stronger, less expensive to produce and less wasteful of material. Stresscoat is used at all stages—from laboratory tests, through pilot models to production units to be sure stresses remain within desired limits. With new ceramic Stresscoat, parts can be immersed in oil or tested at temperatures to 600° F.

SPOTCHECK®

low-cost, fire-safe dye penetrant in spray-on cans

On metal, plastic or other solid materials, Spotcheck provides a low-cost dependable test for medium to large, but still nonvisible, open-to-the-surface defects. Self-contained, pressurized spray cans offer the easy convenient means for handling and applying, or also in bulk. All materials are available in new nonflammable or high-flash formulas.

Spotcheck in-place test for aircraft landing wheel shows crack that is prelude to failure.

Your Testing Problem is "Different?" —Tell Us About It

The applications, uses and answers possible with Magnaflux Test Systems have been barely touched upon in these pages. For lack of room, whole systems have been left out. For instance:

STATIFLUX® . . . electrified particle testing for fired ceramics, glass, porcelain enamel, plastics and other nonconductors . . . with constantly growing use in electronics and missile applications.

PARTEK® . . . filtered particle testing for ceramics and nonporous solids to reveal handling, forming and drying cracks in unfired clay bodies before kiln time is wasted on defective ones.

THERMOGRAPHIC TEST OF HONEYCOMBS . . . Bondcheck is a new fast test for proper bond and integrity in metallic honeycomb sandwiches and certain welded structures, widely useful in aircraft construction, among other applications.

INSPECTION SERVICE

In addition, Magnaflux Corporation maintains its own nationwide Commercial and Field Inspection Service, with plants in 16 principal cities, ready to test one part or one million, on a regular basis or to expand your own test capacity in emergencies.

No matter how unique or how routine your inspection problem, call in the Magnaflux nondestructive testing engineer. For thousands of companies, it has been one of the most profitable steps ever taken.

THE HALLMARK OF Quality IN NONDESTRUCTIVE TEST SYSTEMS

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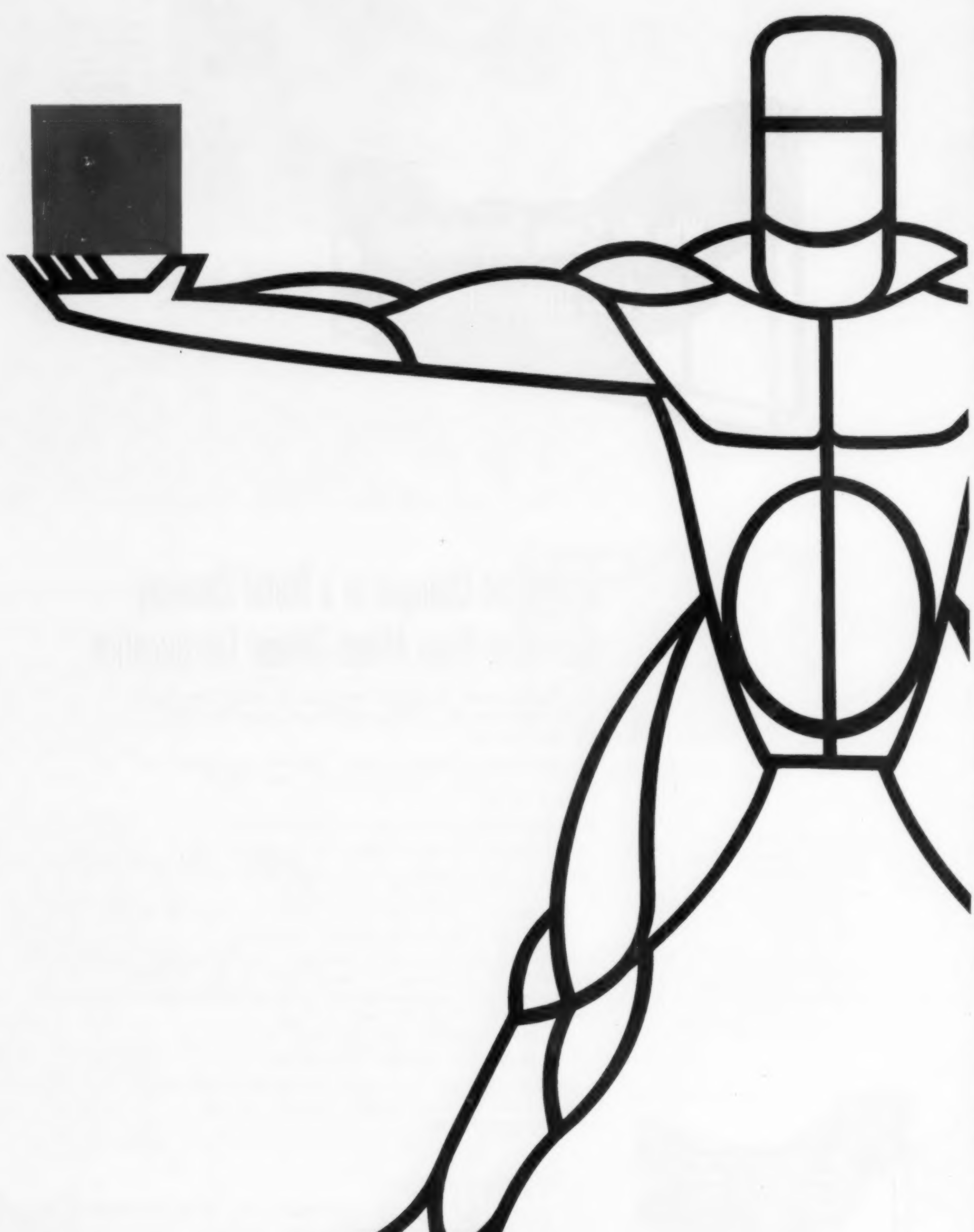
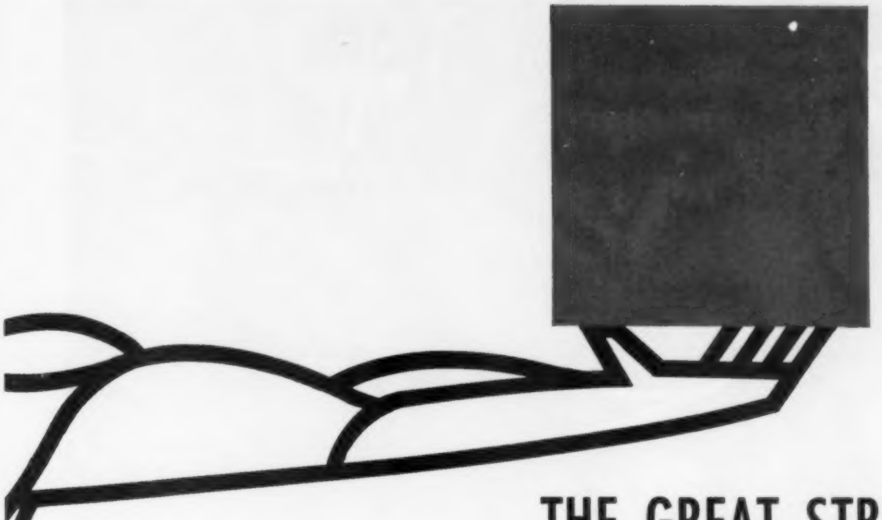
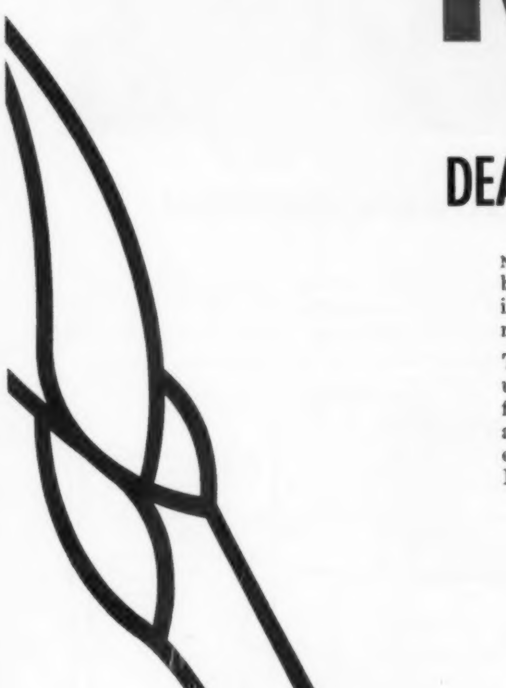


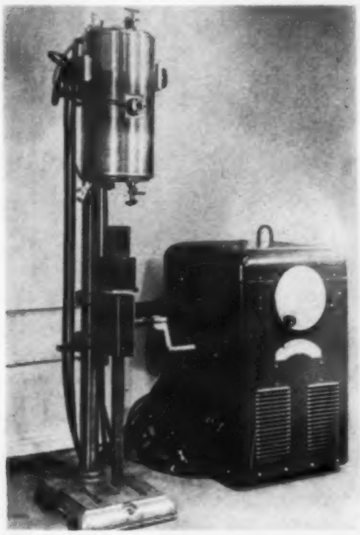




APPLICATION and EQUIPMENT new products

Laboratory Furnace

A laboratory resistance furnace that operates to 5000° F. has been announced by the Santa Barbara Div. of Curtiss-Wright Corp. It has an inert gas atmosphere, graphite heating element and carbon insulation.



The heating chamber of the standard unit is 4 in. in diameter by 8 in. high. A hearth lowers out of the heating chamber for easy access to the interior of the unit. Two sighting tubes are placed at top and side of the furnace. The furnace is available with or without automatic temperature controls.
For further information circle No. 501 on literature request card, page 48-D.

Thickness Measurement

New smaller-size models of a short-pulse X-ray thickness gage have been announced by the Industrial Gauges Dept. of Daystrom, Inc. Designed for thickness measurements ranging from foil thicknesses of 0.00025 in. to plate thicknesses of 1.5 in., the new short-pulse gage uses a sharply-pulsed, pencil X-ray beam to measure thickness from end to end and side to side, at speeds up to 6000 fpm. The new gage consists of a X-ray generator to supply a controlled pulsed beam, X-ray incident unit to detect the amount of transmitted energy, and indicator console containing electronic elements to convert and compute the variation of transmitted energy into terms of thickness variations and to initiate corrective action.
For further information circle No. 502 on literature request card, page 48-D.

Thermocouple Accessory

A new thermocouple head assembly with a hinged steel cap that can be flipped open or shut has been announced by Pyrometer Co. of America, Inc. A positive catch on the lock and the moisture and heat-resistant gasket shield the wires against corrosion, abrasion and mechanical damage. The cap is usually of pressed steel, but stainless steel caps are available. A new ceramic block that will take wires from 8 gage down to the smallest sizes, has been designed to fit snugly in the flip-top head.
For further information circle No. 503 on literature request card, page 48-D.

Metal Sorting

A meter which sorts mixed lots of metal parts by its response to their conductivity and permeability has been announced by Metrol, Inc. The instrument will also test both ferrous and

nonferrous metal parts for heat treatment condition, relative hardness and strength, chemical purity, and presence of decarburization. Measurements are made on any flat surface ⅝ in. in diameter or larger, even when surface is rough, dirty, or covered with layers of paint. Measurements are made in about 3 sec. by touching a hand-held probe to the surface to be tested. The probe radiates an electromagnetic field which excites eddy currents in the test part. Instrument response to conductivity and permeability is displayed on a meter, and by two alarm lights. A variety of plug-in meter scales is available for different metals (see illustration) and conductivity ranges.
For further information circle No. 504 on literature request card, page 48-D.

Ultrasonic Cleaning

National Ultrasonic Corp. has announced a new unit for small part cleaning applications in which high energy density is required. The cleaner

features a 1-gal. heavy-gage polished stainless steel tank with 43% of the bottom covered with driving elements. Actual radiating surface is 12 sq. in. The 115 v., a-c., single-phase, 60-cycle generator, designed for continuous operation, delivers an average power output of 60 watts and produces peaks of 240 watts.
For further information circle No. 505 on literature request card, page 48-D.

Melting Furnace

International Foundry Supply Co. has announced a mobile demonstration unit for on-the-spot demonstrations of the Revecon furnace. The operation of the furnace is demonstrated with the metal used by the foundry being visited. The demonstration consists of melting 100 lb. of aluminum in 12 min. using 0.7 gal. of oil or 100 cu. ft. of 1040 Btu. gas; 200 lb. of brass or bronze in 20 min. using 1.2 gal. oil or 130 cu. ft. of 1040 Btu. gas per 100

From heat to heat...
bar to bar... order to order...

TIMKEN® STEEL GIVES YOU UNIFORM FORGING QUALITY THAT SAVES YOU MONEY

You can get money-saving, uniform forged quality in *your* products just as fine as that in the rock bit forgings pictured here. They're made from Timken® steel forging bars. And the photograph of the bits is not retouched.

Savings are yours because Timken steel is uniform from heat to heat, bar to bar, order to order. It never varies in structure, chemistry or dimension. And because Timken steel is so dependably uniform, you don't have to interrupt operations to adjust your equipment.

Timken electric furnace fine alloy steel is as uniform a forging steel as you can buy because we take extra quality control steps to make it so. One step—a "first" in the U. S. steel industry—is our magnetic stirrer. This assures equal distribution of the alloys, uniform temperature and working of the slag. Another is our unique method of handling orders individually. It enables us to target our procedures to *your* end-use requirements.

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To get the most from your modern forging operations, specify Timken steel forging bars. The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable: "TIMROSCO". *Makers of Tapered Roller Bearings, Fine Alloy Steels and Removable Rock Bits.*

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2. Service from the experts in specialty steels
3. Over 40 years experience in solving tough steel problems.

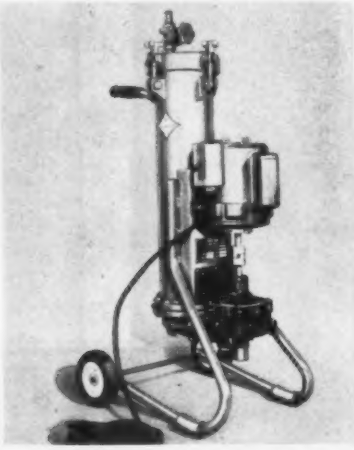
TIMKEN® *Fine Alloy* STEEL

lb.; 175 lb. copper in 35 min. using 1.5 gal. oil or 150 cu. ft. of 1040 Btu. gas per 100 lb.; or 100 lb. of iron in 55 min. using 3.4 gal. oil or 360 cu. ft. of 1040 Btu. gas.

For further information circle No. 506 on literature request card, page 48-D.

Plating Solution Filter

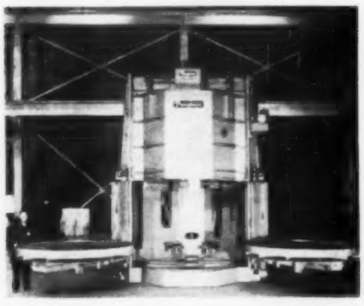
Industrial Filter and Pump Mfg. Co. has announced a low-cost, portable plating solution filter which can be moved from one electroplating tank to another. It is mounted on rubber-tired wheels and is designed to provide 600 gal. per hr. flow capacity and up to 20 sq. ft. of filtration area. It is connected directly to the plating tank. Weighing less than 125 lb. empty and 140 lb. full, the filter requires 3 sq. ft. of floor area.



For further information circle No. 507 on literature request card, page 48-D.

Cleaning Room

A new 8-ft. high twin-table Rotoblast room for cleaning individual castings weighing up to 5 tons has been announced by the Pangborn Corp. With the twin-table system, one work table of the machine is outside where castings or weldments can be reloaded, turned or unloaded while the other table load is revolving inside the blast cabinet being cleaned. The blast cleaner features two Rotoblast wheels with 30 hp. motors capable of throwing 100,000 lb. of abrasive per hour. One of the two wheels is mounted on the top deck of the room, blasting 90° to the table top and the second is positioned to provide thorough cleaning of top and sides of the work.



For further information circle No. 508 on literature request card, page 48-D.

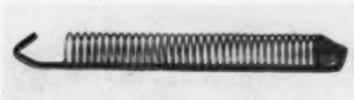
Semiautomatic Welding

A semiautomatic process for welding mild steels with up to 75,000 psi. strength has been announced by Arcos Corp. The process uses a flux-cored electrode continuously fed into the weld puddle where it is shielded by CO_2 gas released from the welding gun. The arc is visible at all times permitting the operator to guide it and control the speed of welding. Arcosarc flux-cored wire is made from metal strip specially formed to hold flux powders and deoxidizing agents which form a protective slag over the solidifying molten metal. The equipment, including the welding gun and semiautomatic wire feed equipment, can be connected to most machines of 500-amp. capacity or larger.

For further information circle No. 509 on literature request card, page 48-D.

Plating Fixtures

A line of anode ball baskets used for zinc plating has been announced by Wiretex Manufacturing Co., Inc. Standard models are of steel, 12 to 36 in. in length, 2⅛ in. in diameter, with a standard 5-in. hook. Basket is designed to hold balls 2 in. in diameter. They are available in steel and other alloys and metals.



For further information circle No. 510 on literature request card, page 48-D.

Heat-Resistant Alloys

Haynes Stellite Co. has announced the availability of several high-temperature alloys in cold rolled thin-gage sheets measuring 0.010 in. thick, 36 in. wide, and 96 in. long. Alloys currently available in this form are Haynes alloy No. 25, Multimet, Hastelloy R-235, Hastelloy X, and René 41.

For further information circle No. 511 on literature request card, page 48-D.

Cleaners

Detrex Chemical Industries has announced a new line of electrolytic cleaners for the removal of intentional

soils from aluminum and aluminum alloys, zinc, steel, brass, copper, nickel, and other metals. The high alkalinity of the new cleaners gives high saponification when not preceded by other cleaning methods. They are recommended for use in batch-type plating shop applications.
For further information circle No. 512 on literature request card, page 48-D.

Batch-Type Furnace

A batch-type, controlled-atmosphere furnace for bright metal finishing in heat treatment has been announced by Surface Combustion Corp. Increased furnace production is obtained by incorporating a specially designed side

cool chamber adjacent to the furnace vestibule. This permits work to move between the heating chamber, furnace vestibule and annealing chamber without leaving the furnace proper. The cooling chamber can cool an 800-lb. load from 1550 to 600° F. in 5 min.
For further information circle No. 513 on literature request card, page 48-D.

Electrocleaner

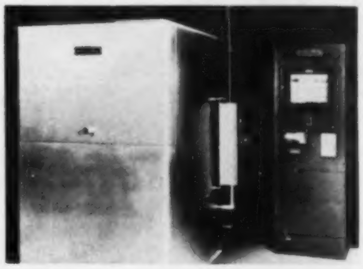
A new heavy-duty, high-conductivity, anodic cleaner for steel has been announced by Enthone, Inc. The new product is designed for anodic cleaning at high current density. Enbond Cleaner FE-84 is furnished as a powder that may be dissolved in water at concentrations of 8 to 12 oz. per gal. and used at 180 to 200° F.
For further information circle No. 514 on literature request card, page 48-D.

Strippers

Heatbath Corp. has announced two new dry powdered products for stripping anodized and oxide coatings from aluminum. Stripal No. 5 is an alkaline powder that can be used in a steel container at 2 lb. per gal. of water without heat for rapid stripping of anodized or oxide coatings. Stripal No. 4 is an acid powder used at 1 lb. per gal. of water at a temperature of 180 to 190° F. for removing anodic coatings leaving the aluminum bright and free from smut. Both products contain inhibitors for preventing attack on the underlying aluminum.
For further information circle No. 515 on literature request card, page 48-D.

Heat Treating

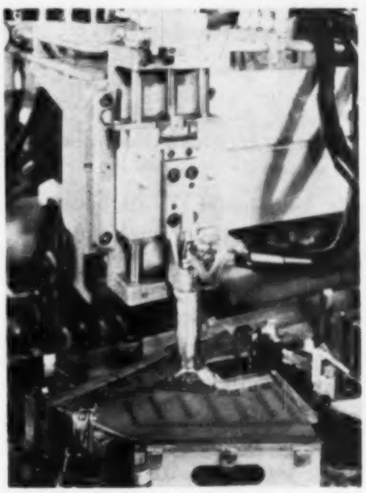
A new controlled-atmosphere electric furnace has been announced by Waltz Furnace Co. Doors are air-



operated by means of a foot valve. Ribbon of 80% Cr—20% Ni of extra large cross section forms the elements which are looped and slid into grooves in the refractory lining. The elements operate on 110 v. from 220 or 440 v. step-down transformers located in the base of the furnace.
For further information circle No. 516 on literature request card, page 48-D.

Welding Equipment

The Linde Co. has announced a new pilot-arc for positive-arc starting for inert-gas tungsten-arc spot welding or cutting especially in mechanized



installations where torches must be fired according to a predetermined schedule. Pilot-arc starting eliminates all high-frequency interference problems and avoids the contamination problems of retract starting. The pilot-arc keeps a ball of incandescent gas within the cup so that the arc is always ready to fire as soon as potential is applied between torch and workpiece. The current is adjusted to about 5 amp. and is maintained between electrode and water-cooled nozzle. A small quantity of shielding gas flows

continuously and protects the electrode while the pilot is on. When the torch is brought into welding position against the work, and the trigger pulled, the pilot-arc provides a path for the main welding current which instantaneously flashes across to the work and makes the spot weld.
For further information circle No. 517 on literature request card, page 48-D.

Stainless Steel Plates

G. O. Carlson, Inc., has announced plates of Type 304 stainless steel which measure 461 by 179 by 2 in. and 451 by 184 by 2 in. and weigh over 49,000 lb. each. They were pro-

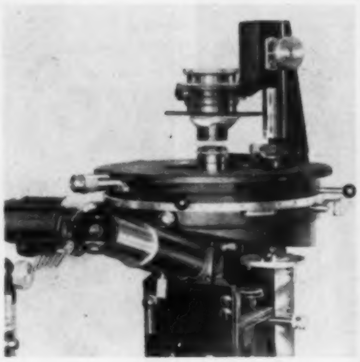
duced to ASTM A240, Grade S for use in an atomic energy application. The melt was prepared in a 70-ton capacity furnace and poured into extra large ingot molds. Then these ingots were slabbed and rolled into plates. The plates were flame and abrasive-cut into two huge semi-circles.
For further information circle No. 518 on literature request card, page 48-D.

Cement

A new thermosetting carbonaceous cement has been announced by the Electrode Div., Great Lakes Carbon Corp. The one-package premixed cement is available in a range of consistencies and is ready for immediate application without stirring. The cement is specially designed for high-strength bonding of carbon-brick blast-furnace linings and graphite blocks in chemical equipment.
For further information circle No. 519 on literature request card, page 48-D.

Specimen Holder

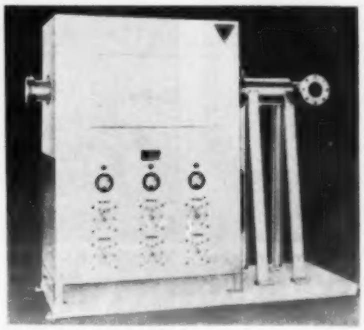
A magnetic specimen holder that can be used with any inverted metallurgical microscope has been announced by William J. Hacker & Co. This holder permits survey of small specimens without embedding them. Using plasticine or a similar product and a specimen press, the sample is attached to a metal object slide that is then placed under the magnet of the specimen holder. The tension between slide and magnet can be regulated and the slide with the specimen can be shifted into any desired posi-



tion for survey of the entire sample without marring its surface.
For further information circle No. 520 on literature request card, page 48-D.

Tube Furnace

The Pereny Equipment Co. has announced a new gas-tight electric tube furnace for work requiring temperatures up to 2800° F. It has a 5-in. I.D. impervious mullite tube, with silicon-carbide heating elements spaced equidistant around it, and providing a 30-in. long hot zone with three separate zone controls for temperature

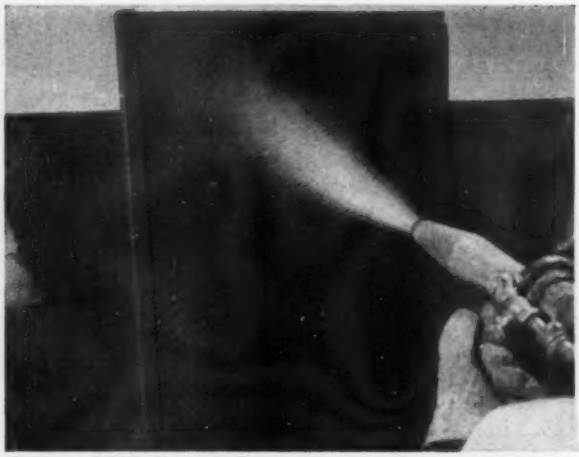


control. Separate transformers, on each of three phases, are of the voltage regulating type with 36 fine-to-coarse taps. The over-all length of the unit is 60 in.
For further information circle No. 521 on literature request card, page 48-D.

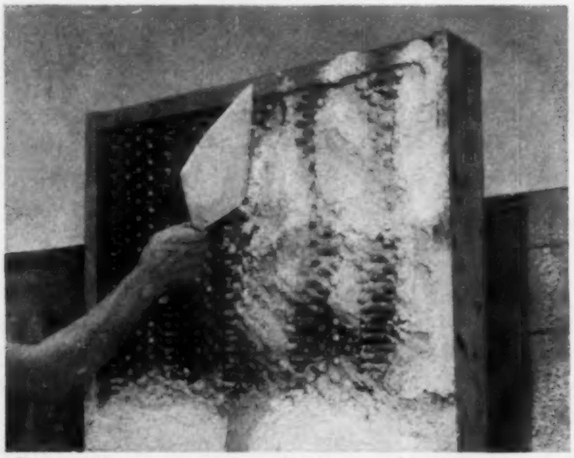
Rolling Mill

A two-high/four-high combination rolling mill for nuclear metals production and research work has been announced by Loma Machine Manufacturing Co., Inc. The new machine is completely enclosed to allow the processing of reactive metals. To facilitate remote control operation, the mill is equipped with a semi-automatic roll changing device comprising a sliding way, a quick-disconnect screwdown, a universal spindle support and pull-off oil lubrication lines. The entire roll assembly may

Casting furnace linings in place can be speedily accomplished with any B&W Refractory Castable. Here, tough, erosion-resistant B&W Kaocrete-D is cast in a lining that will be ready for service soon after installation.



Gunning B&W Kromight-Gun assures complete penetration of irregular areas. This 3200 F refractory material is excellent for studded open hearth doors and similar metalworking installations.



Slap trowelling can be the most effective way of forming a vertical or overhanging section of lining, provided the castable has an exceptionally adhesive, plastic texture. B&W Kaocrete-B, possessing these properties, is widely used in this type of installation.

Vibrating B&W Kaocrete-32 in place to form electrode rings in an electric furnace. This method of installation provides density and strength, and eliminates laminations, air bubbles and pockets, thus permitting economical, long life.

How B&W refractory castables solve application problems

Installing refractory linings quickly and inexpensively is a major concern of furnace builders and operators. Each of the many different types of metal working furnaces presents its own particular installation problems. To meet these widely differing conditions, B&W offers not just one, but a range of *specialized* refractory castables. Each is *engineered* to provide savings in installation time. *Specialized* B&W Refractory Castables save money by eliminating the need for costly inventories of special shapes. The use of castables speeds up new construction and repair jobs and permits simplified, improved furnace design together with long life—in short, superior performance over a wide range of furnace operating conditions.

B&W Bulletin R-35A gives additional information on versatile B&W refractory castables. Write for copy to The Babcock & Wilcox Company, 161 East 42nd Street, New York 17, N. Y.

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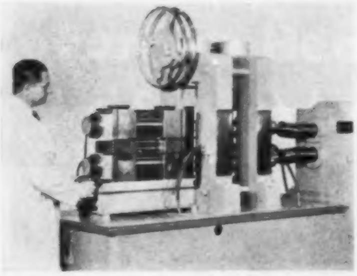
R631

THE BABCOCK & WILCOX COMPANY

REFRACTORIES DIVISION

B&W Firebrick, Insulating Firebrick, and Refractory Castables, Plastics, Ramming Mixes, Mortars, and Ceramic Fiber.

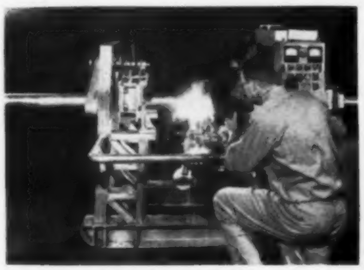


be moved into or out of the mill, and roll changes can be made.

For further information circle No. 522 on literature request card, page 48-D.

Pipe Welding

A new automatic pipe welding machine capable of producing welds with full penetration without the use of back-up rings has been announced by Aluminum Co. of America. The unit completes a pass on 4-in. pipe in 11 sec. It can process all tubular products with outside diameters of 4 to 11 in. Vapor-proof cabinets contain all elec-



trical controls. Head of a new automatic machine can be positioned through a range of welding angles, and can be set to oscillate, automatically moving back and forth across weld width to insure complete filling.

For further information circle No. 523 on literature request card, page 48-D.

Temperature Chamber

Missimers, Inc., has announced a new chamber for production processing and testing at temperatures from -100 to $+350°$ F. This bench-type unit has a 1-cu. ft. working space. It employs the cascade mechanical refrigeration system for low temperatures and nichrome wire elements for heating. One 115 v. outlet furnishes sufficient power.

For further information circle No. 524 on literature request card, page 48-D.

Metal Cutting

A new, dual version of their industrial airbrasive unit has been announced by S.S. White Industrial Div. This tool cuts or abrades almost any hard or brittle material. The Duplex Model D combines two units in one housing, making possible added capacity or a choice of abrasive materials. The airbrasive unit cuts or abrades with a controlled stream of gas-propelled abrasive, emerging from the cutting tip nozzle at 1100 ft. per sec. The abrasive material ordinarily employed is aluminum oxide in the 27

micron range. Any compressed gas source of 80 psi. can be used, as long as the gas is dry.

For further information circle No. 525 on literature request card, page 48-D.

Graphite Tube Furnace

A new high-temperature graphite tube furnace has been announced by

the Pilot Plant Equipment Div. of Lindberg Engineering Co. It may be used for sintering of powder metals. The over-all operating temperature range is 1600 to 5000° F.

For further information circle No. 526 on literature request card, page 48-D.

Welding Positioners

A new device regulating travel speed of parts of various diameters to be welded has been announced by Harnischfeger Corp. One dial sets for inches per minute, another for weld diameter to the nearest 0.01 in. Both can be varied while the weldment is in motion. In addition to full control of rotation and tilt, both forward and reverse, there is a switch which permits maximum table revolutions per

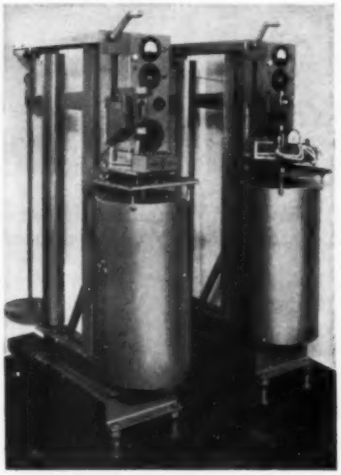
minute without disturbing the other weld settings.
For further information circle No. 527 on literature request card, page 48-D.

Temperature Control

The maximum size of the d.c. saturable reactors manufactured by Sorgel Electric Co., and described in the June issue of Metal Progress should have been 3000 kva. instead of 300 kva. These reactors are used for controlling and regulating the temperature of electric furnaces. Units consist of a laminated steel core and a series of coils similar to a transformer in which the core is magnetized and saturated to a varying degree by d.c. current.
For further information circle No. 528 on literature request card, page 48-D.

Creep Testing Machines

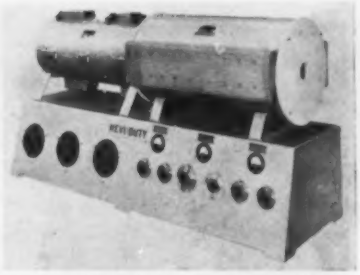
A new line of stress-rupture-creep testing machines has been announced by the Tinius Olsen Testing Machine Co. Two models are currently available—140 to 6000 lb. or 280 to 12,000 lb. Testing temperatures to 2462° F.



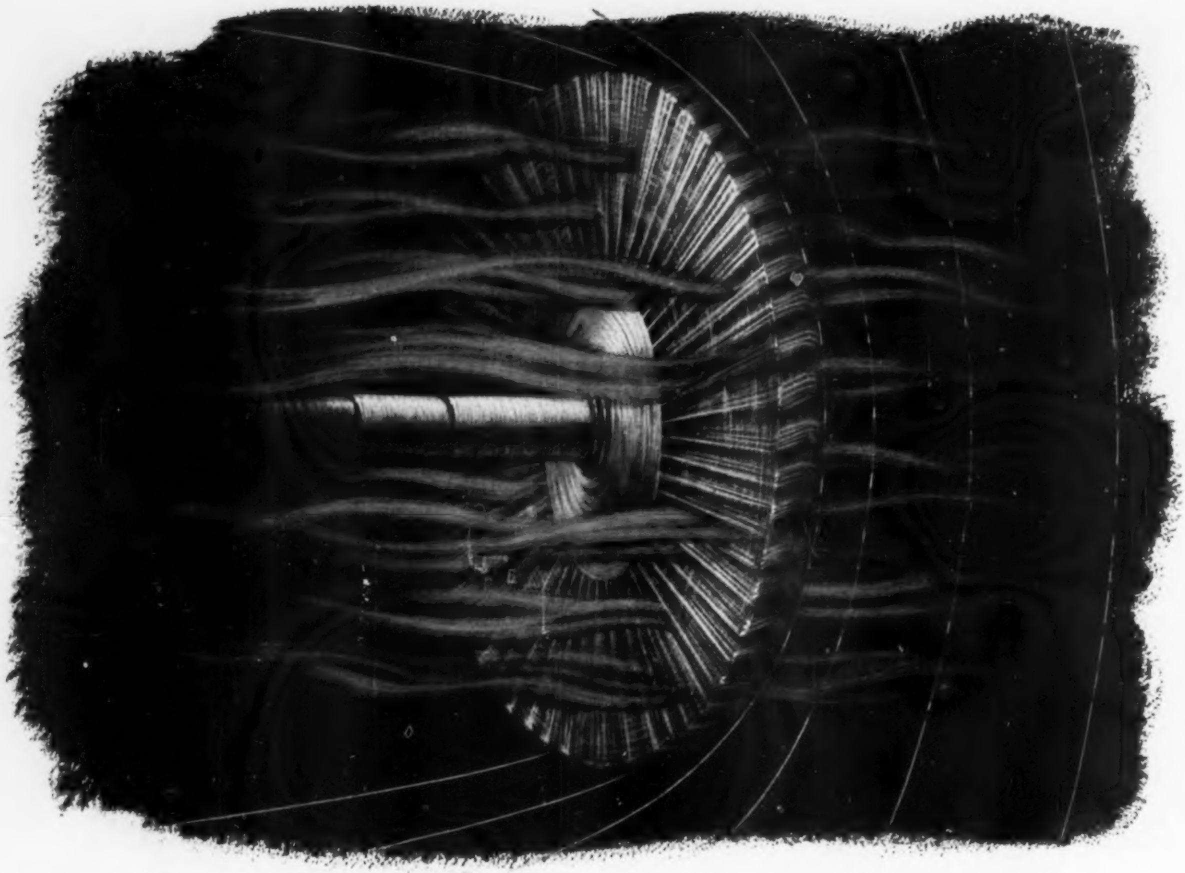
are maintained within ±2° F. by an integral thermostat in three individually regulated and controlled heating zones. Specimen extension or creep is indicated on a large dial indicator with 0.001-in. graduations.
For further information circle No. 529 on literature request card, page 48-D.

Furnaces

Hevi-Duty Electric Co. has announced several standard precision furnaces for the transistor and semiconductor industries. They are available in three maximum temperature ranges of 1850, 2200, and 2600° F. Temperature uniformity is assured through multiple-zone heating. Saturable reactor controls provide precise temperature selection. Controlled pre-



heat and cooling zones can also be supplied with the furnaces.
For further information circle No. 530 on literature request card, page 48-D.



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Extremely high centrifugal forces, plus prolonged operation well above 1700 deg. F.! That's the achievement of thousands of jet engine turbine wheels and blades investment-cast of HAYNES high-temperature alloys.

Resistance to stress, to thermal shock, to erosion, corrosion, and to fatigue are typical properties that make these alloys so extremely useful in many of the hot spots in today's jet engines, ramjets, missiles, and rockets.

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DETROIT, MICHIGAN FORT WORTH, TEXAS LOS ANGELES, CALIFORNIA

APPLICATION and EQUIPMENT new literature

532. Abrasive Cleaning
Folder on Malleabrasive for airless blast cleaning equipment gives advantages, grades, equipment it can be used with and parts that can be cleaned. *Globe Steel Abrasive*

533. Abrasive Cleaning
Catalog 57-WX on brush types, sizes, speeds, filaments. Aids to power brush selection. *Pittsburgh Plate Glass*

534. Abrasives
New catalog covering SAE specifications on all types of abrasive shot, grit and cut wire. Methods and advantages of shot peening and impact cleaning, and the proper abrasive mixtures. *Cleveland Metal Abrasive*

535. Alloy Steel
16-page book on type 9115 low-alloy high-strength steel. Properties, fabrication, welding. *Great Lakes Steel*

536. Alloy Steel
68-page "Aircraft Steels" includes revised military specifications. Also stock list. *Ryerson*

537. Alloy Steels
Article on use of chromium-molybdenum-vanadium steel for service at elevated temperatures. Chemical composition, mechanical properties. Vancoram Review, V. 13. No. 1. *Vanadium Corp.*

538. Aluminum Casting Alloys
8-page bulletin on aluminum casting alloys. Properties; selection of casting method: pig, ingot and billet compositions. *Metals Div., Olin Mathieson Chemical Corp.*

539. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

540. Aluminum Extrusions
Folder lists alloys used, finishes, trade phraseology. *General Extrusions*

541. Ammonia
8-page booklet on uses of dissociated ammonia in industry. Dissociation process and applications in bright annealing, furnace brazing, powder metallurgy, bright hardening. *Armour Ammonia*

542. Ammonia
69-page data book on anhydrous ammonia and ammonia liquor. Chemical and physical properties, specifications, analytical procedures, bibliography. *Nitrogen Div.*

543. Atmosphere Cooling
Bulletin T-40 on automatic heat treating units with controlled atmosphere cooling. *Ipsen*

544. Atmosphere Equipment
Bulletin No. I-101 on carbon dioxide removers. Design features, data chart, operation. *C. M. Kemp*

545. Beryllium Copper
New data sheets on three copper beryllium alloys. Analysis, physical constants, mechanical properties, heat treating procedures. *Pennrold Div., Brush Beryllium*

546. Beryllium Oxide
12-page booklet on properties, chemical analysis and applications of UOX beryllium oxide, a sinterable grade of refractory oxide of beryllium. *Brush Beryllium*

547. Blast Cleaning
12-page booklet on blast cleaning equipment describes vacuum-cast heat treated steel abrasive. *Pangborn*

548. Brazing
Brazing News No. 79 tells of silver brazing's characteristics. Case histories. *Handy & Harman*

549. Brazing Alloys
Standard compositions, specifications for high-purity brazing alloys for copper, bronze, brass. *Alloy Specialties*

550. Carbon and Graphite
Catalog Section S-5008 on carbon and graphite products for chemical operations includes heat exchangers, pumps, pipe and fittings. *National Carbon*

551. Casting Alloys
Compact, 28-page guide to nickel-containing casting alloys gives properties, compositions, uses of major alloys. *International Nickel*

552. Castings
New catalog on forging and casting products contains information on air hardening, oil hardening and other cast-to-shape tool steel specialties. *Allegheny Ludlum*

553. Castings
Data on castings of aluminum, magnesium and ductile iron for shock resistance. *Morris Bean & Co.*

554. Castings
Brochure on plaster mold castings of brass, bronze, aluminum, beryllium copper. *Ohio Precision Castings, Inc.*

555. Centrifugal Castings
16-page brochure on use and specifications of centrifugally cast cylinders, other products. *Sandusky Foundry & Machine*

556. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

557. Chromium Stainless
12-page book on fabrication and use of Type 430 stainless steel. *Sharon Steel*

558. CO_2 Welding
New 38-page booklet on inert-gas-shielded-arc welding of mild steel and low alloy steels with carbon dioxide shielding gas. *Hobart Bros.*

559. Coatings
4-page catalog on heat-proof protective coatings. Basic types, applications, methods of applying and temperature ranges. *Markal Co.*

560. Cold Forming
4-page folder on die-form process for cold reduction of steel bars into multi-diameter shaft blanks for finish turning or grinding. *Republic Steel*

561. Cold Rolling
Description of advantages of cold rolling of ship propeller shafting. How it is done. *Erie Forge & Steel*

562. Compressors
12-page Bulletin 126-A on application of turbo compressors to oil and gas-fired equipment used in heat treating, agitation, cooling, drying. Performance curves, capacities. *Spencer Turbine*

563. Controller
12-page bulletin on new impulse-sequence time-cycle controller and its uses. *Bristol Co.*

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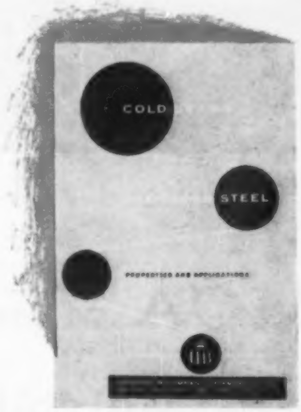
531. Stainless Wire

Starting with a general description of the rust-resisting, acid-resisting and heat-resisting steels, this 77-page booklet then goes on to give the analyses and properties of the austenitic, ferritic and martensitic stainless steels with special



emphasis on the properties produced by cold drawing. Many charts and tables present data in an easy-to-use form. The last half of the booklet pictures and discusses the hundreds of applications of cold drawn stainless steel wire. *Uddeholm Co. of America*

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564. Controllers
Data on controllers and recorders. *Samuels Sons Iron & Steel Co.*

565. Copper Alloys
28-page specification index compares trade names and specifications of various agencies. Compositions of alloys. *American Brass Co.*

566. Cutting Oil
Folder describing nine types of cutting oils for varied applications. *Gulf Oil Corp.*

567. Cutting Tools
4-page Bulletin CT-175 gives specifications and descriptions of hack saw blades, hole saws, band saw blades. *Armstrong-Blum Mfg.*

568. Deburring
2-page data sheet on chemical solution for removing burrs raised by drilling or other diecasting operations. *MacDermid, Inc.*

569. Degreaser
Folder on automatic degreaser. Cleaning and solvent cycles described. Features of equipment. *Detrex*

570. Degreasers
Folder on vapor and solvent degreasers describes equipment and advantages. *Randall Mfg.*

571. Degreasing
Booklet on vapor degreasing. Design, installation, operation and maintenance of equipment. *Circo Equipment*

572. Degreasing
Bulletin No. 70 on degreasing with trichlorethylene. Advantages and disadvantages. *Hooker Electrochemical*

573. Descaling
Bulletin 609 describes line of descaling machines, equipment, processes for metal cleaning. *Pangborn*

574. Die Steel
Folder and stock list on Olympic FM air hardening, high carbon-high chromium die steel with sulphide additives for improved machinability. *Latrobe Steel Co.*

575. Ductile Iron
Bulletin on magnesium ferrosilicon for ductile iron. Analysis of magnesium ferro alloys. Role of magnesium in ductile iron. *Union Carbide Metals*

576. Electric Furnaces
8-page Bulletin 570 on heat treating, melting, metallurgical tube, research and sintering furnaces. Custom designs for special requirements. *Pereny*

577. Electric Heat
New Bulletin GER-1333 on electric heat for plating baths. Installation, power and maintenance. *General Electric*

578. Electron Microscope
20-page brochure describes ten case histories in which the electron microscope has been at work solving problems of development and control in industrial laboratories. *RCA*

579. Electroplating
Chart gives reference data for gold, rhodium, palladium, platinum, silver, nickel plating. *Technic*

580. Environmental Testing
New folder on temperature-humidity chambers, from 2 cu. ft. portable to 10 cu. ft. production model. *Harris Refrigeration Co.*

581. Extrusions
Bulletin on extruded seamless alloy and stainless steel tubing. Properties, shapes. *Metals Processing Div., Curtiss-Wright*

582. Finish
Data on production finishes for grinding, polishing and deburring of flat work. Specifications. *Hammond Machinery Builders*

583. Finish
New 4-page folder on heat-resistant coating. Properties, performance data on black and aluminum Sicon coatings. *Midland Industrial Finishes Co.*

584. Finishing
Bulletin on Unichrome coating 6400, a vinyl coating with the appearance of leather. Coating procedure. Advantages. *Metal & Thermit*

585. Finishing Processes
30-page catalog describes types and processes of finishing. Machines, accessories, applications. *Roto-Finish Co.*

586. Flame Hardening
New 4-page catalog on flame hardening steels, cast iron, nodular iron. Parts flame hardened. Hardnesses produced. *Chicago Flame Hardening Co.*

587. Flow Meters
Catalog on flow meters for gases, liquids and combinations. Also line of manometers. *Seico Div., Eclipse*

588. Flow Meters
Bulletin 203 on flow meters for gas used in heat treating. *Waukee Eng'g.*

589. Forgings
Bulletin on forge steelmaking, open die forging, machining, heat treating and finishing. *National Forge*

590. Forgings
Folder on facilities for production of flat-die forged products. Electronic equipment used. *Smith-Armstrong*

591. Formed Plate
Bulletin on stainless steel ASME and standard flanged and dished heads. 352 available dies listed. *G. O. Carlson*

592. Formed Shapes
Catalog No. 1053 describing numerous formed shapes made from ferrous and nonferrous metals. *Roll Formed Products*

593. Freezer
Data on chest for use down to −140° F. for production and testing. *Revco*

594. Furnace
Bulletin 5709 on vacuum heat treating furnace. Temperature range 600 to 2150° F. Design features, performance data and applications. *C. I. Hayes*

595. Furnace
6-page Bulletin No. 805 on laboratory vacuum furnace. Specifications, applications, accessories. *Kinney Mfg.*

596. Furnace Belts
44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

597. Furnace Controls
Bulletin 658 on saturable reactor for regulation and control of electric ovens and furnaces. *Sorgel Electric Co.*

598. Furnace Fixtures
16-page catalog on baskets, trays, fixtures and carburizing boxes for heat treating. 66 designs. *Stanwood*

599. Furnaces
Bulletin No. 461 on gas, oil and electric furnaces. 17 different installations described. *Electric Furnace*

600. Furnaces
List of industrial furnaces and equipment in stock. *TherMaTek Co.*

601. Furnaces
8-page bulletin on pit-type convection furnaces. Uses, construction, atmospheres, specifications. *Hevi-Duty*

602. Furnaces
Bulletin 200 describes complete setup for heat treatment of small tools, including draw furnace, quench tank and high-temperature furnace. *Waltz Furnace*

603. Furnaces
12-page catalog on electric heat treating furnaces. Data on each of 57 models. Controls, instruments, elements and accessories. *Lucifer Furnaces, Inc.*

604. Furnaces
List of used furnaces in stock. *Papesch & Kolstad, Inc.*

605. Gas Analyzers
20-page booklet on continuous analyzers for combustible gases. Alarm systems. *Mine Safety Appliances Co.*

606. Gold Plating
8-page brochure gives bath composition, equipment and operating conditions, and metallurgical characteristics of 24K

gold plate on various base metals. *Sel-Rex Corp.*

607. Graphite Electrodes
6-page folder describing graphite electrodes for electric furnaces. Stock list of threaded graphite electrodes and their corresponding nipples. *Great Lakes Carbon*

608. Hardness Numbers
Pocket-size table of Brinell hardness numbers. *Steel City Testing*

609. Hardness Tester
Bulletin TT-59 on tester for measuring standard Rockwell and superficial hardness. *Wilson Mechanical Instrument*

610. Hardness Tester
Bulletin F-1689-3 on Impressor portable hardness tester for aluminum, aluminum alloys and soft metals. *Barber-Colman*

611. Hardness Tester
Bulletin S-33 on vertical-scale and dial-indicating scleroscopes. How they are calibrated. *Shore Instrument*

612. Hardness Tester
Catalog 72-1 on Leitz miniload tester for Vickers and Knoop hardness tests. *Opto-Metric Tools, Inc.*

613. Hardness Tester
Bulletin on Brinell tester with test head for deep and offset testing. *King Tester*

614. Hardness Testers
Folder on portable hardness testers for testing of various sizes, shapes and types of metal. *Newage Industries*

615. Hardness Testers
26-page booklet on special Rockwell hardness testers such as motorized and internal testers, and accessories. *Wilson Mechanical Instrument Div.*

616. Hardness Testing
Bulletin A-18 on Alpha Co. Brinell hardness testing machines. *Gries Industries*

617. Heat Treat Pots
Catalog on pressed steel pots for lead, salt, cyanide, oil tempering and metal melting. *Eclipse Industrial Combustion*

618. Heat Treat Pots
6-page folder gives stock shapes and sizes. Tips on installation and use. *Electro-Alloys Div.*

619. Heat Treating
Folder on shaker-hearth furnaces and push-through muffle furnaces for annealing, hardening and brazing stainless steel. *American Gas Furnace Co.*

620. Heat Treating
8-page bulletin on heat treating. Data sheets on processes and processing equipment. Also covers annealing, brazing and hardening. *Ferrotherm*

621. Heat Treating
Monthly bulletin on used heat treating and plating equipment available for immediate delivery. *Metal Treating Equipment Exchange*

622. Heat Treating Dies
Article in Heat Treat Review, Vol. 10, No. 1 on heat treating of precision dies. *Surface Combustion Corp.*

623. Heat Treating Fixtures
24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

624. Heat Treating Fixtures
16-page Catalog M-7 on heat treating baskets and corrosion-resistant-alloy fabrications. *Wiretex Mfg. Co.*

625. Heat Treating Furnaces
42-page catalog on line of furnaces and ovens for heat treating and accessory equipment. *K. H. Huppert Co.*

626. Heat Treating Guide
Chart guide constructed on slide rule principle for simplified hardening and drawing of tool steels. *Carpenter Steel*

627. Heat Treatment
4-page bulletin on a home study and in-plant course on heat treatment of steel. *ASM Metals Engineering Institute*

628. Heating
Bulletin on Heat-O-Coil resistance wire for preheating and stress relieving. *Arcos Corp.*

629. Heating Elements
12-page bulletin gives typical applications of silicon carbide heating elements. Hints on handling, unpacking, storage, installation, replacement. *Globar Div., Carborundum*

630. Heating Elements
24-page booklet on elements for electric furnaces and kilns includes technical data, uses, physical and electrical specifications. *Norton*

631. High-Strength Steel
26-page booklet on properties, uses, applications of high-tensile low-alloy steel. *Jones & Laughlin*

632. High-Strength Steel
24-page bulletin on steel bars made by elevated temperature drawing. Strength without heat treatment, machining, wearability. *LaSalle Steel*

633. High-Temperature Properties
Metallurgical facilities for elevated temperature mechanical properties evaluation. Pocket-size circular slide rule. *Joliet Metallurgical Laboratories*

634. Induction Heaters
12-page bulletin gives descriptions, technical data on various sizes. Water systems diagramed, standard accessory equipment. *High Frequency Heating Div., Lindberg Engineering*

635. Induction Heating
8-page bulletin on high-frequency motor-generator sets for induction heating. *Ohio Crankshaft*

636. Industrial Furnaces
Folder on batch, automatic, continuous gas, electric and oil furnaces. Selection chart shows which operations may be performed in which type of furnace. *Sunbeam Equipment Corp.*

637. Inspection
Bulletin on Spotcheck dye-penetrant inspection. Advantages, prices. *Magnaflux*

638. Inspection
Data on ultrasonic inspection and thickness measurement service in field or laboratory. *Sperry Products*

639. Insulating Firebrick
8-page Bulletin R-43 gives description of relationship between heat losses and weight of refractory lining. *Babcock & Wilcox, Refractories Div.*

640. Insulators
Bulletin P1-55 on insulators and insulating tubing. *McDanel Refractory Porcelain*

641. Investment Casting
"Pointing the Way" presents seven case histories on advantages of investment castings. *Engineered Precision Casting Co.*

642. Laboratory Equipment
Bulletin on cutting test specimens describes methods for different types of metals. Price list. *Sieburg Industries*

643. Laboratory Furnace
Data on nonmetallic resistor furnaces for research, testing or small-scale production. *Harrop Electric Furnace*

644. Laboratory Furnaces
Folder describes and illustrates tubular furnace for use in tensile testing, and control panels. *Marshall Products*

645. Leaded Steels
16-page booklet on basic characteristics, mechanical properties and workability of leaded steels. Case histories. *Copperweld Steel Co.*

646. Lubricant
Bulletin 426 on use of colloidal graphite for forging, wire drawing, piercing, drawing, extrusion and other metalworking operations. *Acheson Colloids*

647. Malleable Iron
New Data Unit No. 102 on importance of tensile strength, yield strength, fatigue strength and other strength factors, especially as applied to malleable irons. *Malleable Castings Council*

648. Manganese
Technical Data Bulletin 201 on electromanganese and nitrelmang. Product characteristics. Composition. *Foote Mineral*

649. Marking
Data on Paintstik markers for identification of heat treated parts. *Markal Co.*

650. Marking Machines
Bulletin 146-C25 and 146-C26 on complete line of marking machines, stationary and portable. For polished surfaces, precision finished parts, glass, ceramics. *Jas. H. Matthews*

651. Meehanite Castings
12-page booklet on castings for cams, camshafts and crankshafts describes specific applications. *Meehanite Metal*

652. Melting
Bulletin 14-B on high frequency furnaces for melting ferrous and nonferrous alloys. High temperature applications up to 3600° C. *Ajax Electrothermic Corp.*

653. Metal Cleaning
32-page Bulletin 10,001-G on methods, materials and equipment for cleaning and preparing metal surfaces. *Magnus Co.*

654. Metal Cleaning
Folder lists products for immersion, electrolytic, spray cleaning, other cleaning agents. *Northwest Chemical*

655. Metal Cutting
56-page Catalog No. 32 gives prices and describes complete line of rotary files, burs, metalworking saws and other products. *Martindale Electric*

656. Metal Marking
Bulletin on all-purpose electric pen which will etch any metal. *Newage*

657. Metal Powders
New 8-page brochure gives information on prealloyed metal powders and tool steels used in powder metal parts production. *Vanadium-Alloys Steel Co.*

658. Metal Sorting
Data on nondestructive sorting of raw, semifinished or finished parts. *J. W. Dice*

659. Metallograph
Bulletin on metallograph operated from sitting position. Transitions are instantaneous. Accessories are interchangeable. *Wm. J. Hacker*

660. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Torsion Balance*

661. Microscope
Technical Bulletin HHS-2 on vacuum heating stage which permits specimens to be examined at temperatures ranging

(Continued on page 48-A)


Here's
where
Thermocol...


THERMOCOL

AUGUST—Selected supplier of anhydrous ammonia . . . assuming that service included technical advice "during use".

LATER—Ammonia system installed without supervision . . . not tested by supplier . . . some parts not designed for ammonia use.

STILL LATER—Had improper atmosphere mixture . . . undesirable case properties . . . sooting and added handling of "finished" parts.

TOO LATE—Too many rejects . . . supplier unable to aid on application. Labor, material and operating costs up . . . profits down.

BE TROUBLE-FREE! Buy your ammonia from Armour. And receive expert technical service—whenever you need it —at no added cost.

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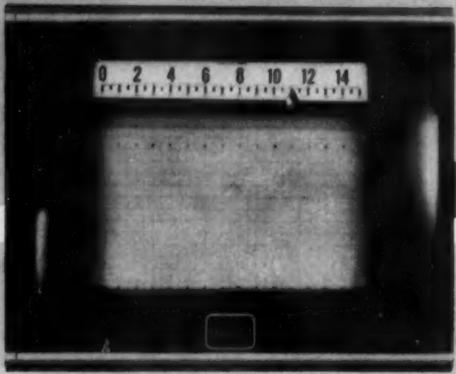
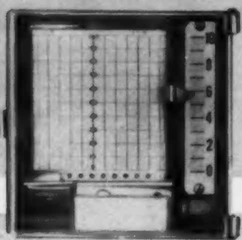
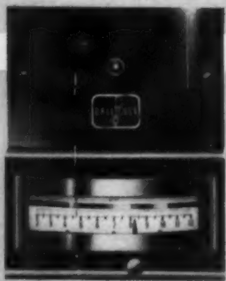
Serving industry for more than half a century with the purest ammonia money can buy.



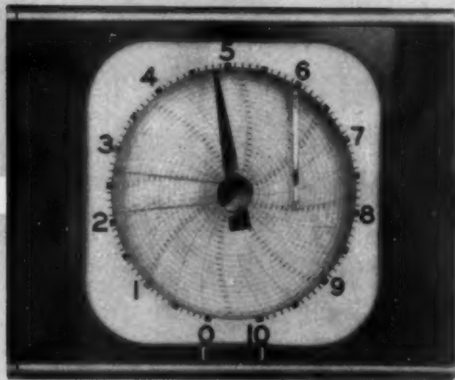
Dynamaster Electronic Potentiometer Pyrometer—Strip-chart model records on chart 11" wide, 120' long.



Miniature Electronic Dynamaster Pyrometer—Records on 3" strip-chart. Indicator model features easy-to-read 9" scale length.



Bristol Millivoltmeter Pyrometers—Free Vane* pyrometer controllers (shown) or indicating types. Many control modes available.



Dynamaster Electronic Potentiometer Pyrometer—Round-chart model records on 12" chart, indicates on extra large scale.

MODERN PYROMETERS...key to profitable use of HEAT

Bristol recording and automatic controlling pyrometers for temperatures up to 5000°F can help you increase product uniformity, cut fuel and maintenance costs

Bristol makes a wide range of pyrometers for every requirement: Electronic potentiometers, millivoltmeter and radiation types . . . for furnaces, ovens . . . every type of heating equipment, every kind of fuel. The reliability and accuracy of these precision instruments have been proved in thousands of installations.

Take just one advanced Bristol instrument, for example, the Electronic Dynamaster* Potentiometer Pyrometer:

CONTINUOUS STANDARDIZATION PLUS ACCURACY OF STANDARD CELL

Continuous standardization in Dynamaster Electronic Pyrometers requires no dry-cells, **but still retains the precision standard cell for highest stability and accuracy of voltage reference.** Results: No interruption to operation, no batteries to change. And here are just a few of the Dynamaster types available:

A model for every requirement: Dynamaster Pyrometers are available as single-pen, two-pen, and multiple-record (up to 24 points) *strip-chart* instruments and as *round-chart* instruments.

Electric and pneumatic controllers: Both strip- and round-chart instruments are made in a very wide variety of controllers that meet every furnace and oven control requirement, including the following in a great many forms:

Electric Control—on-off, proportional input, 3-position, proportioning, proportional with automatic reset, and time-program.

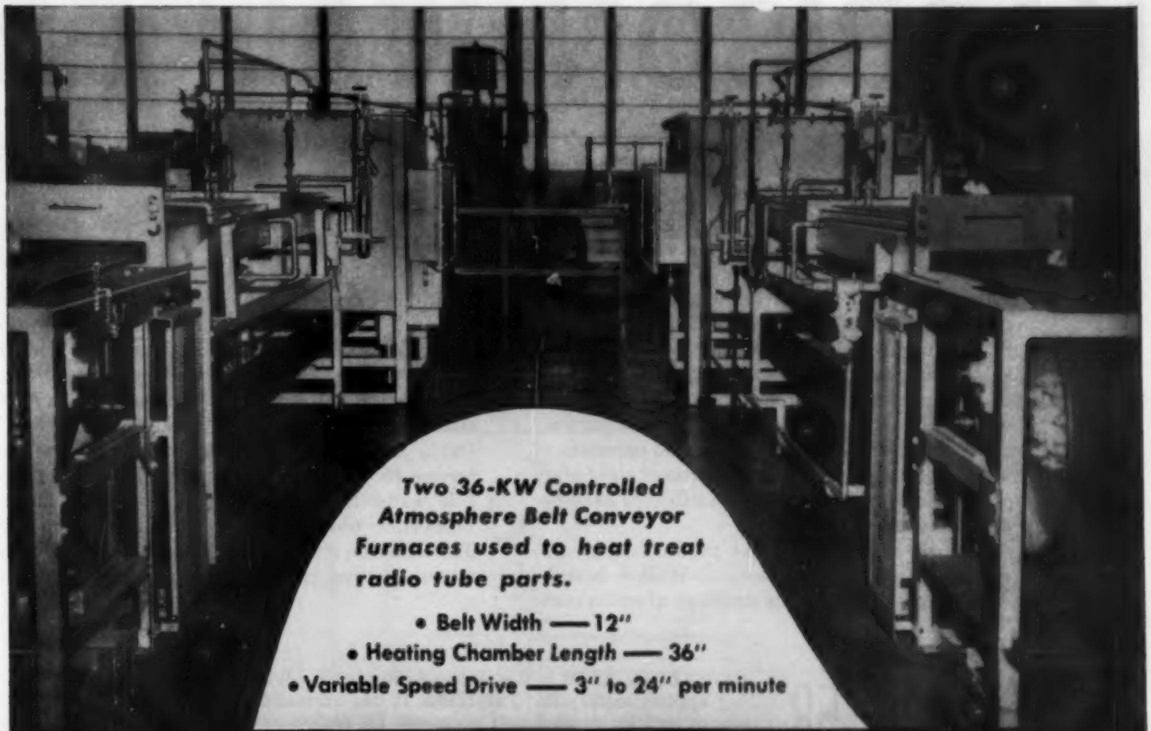
Pneumatic Control—on-off, proportional, and proportional with reset.

Miniature Dynamaster Pyrometer: Full plug-in flexibility . . . takes only 5" x 5⅛" of panel space, but has same basic accuracy, same time-tested operating principle as full-size Dynamaster pyrometers described above. Ideal for graphic panels and centralized recording or indicating of large numbers of variables. Either electrical or pneumatic control types available.

Write for complete data on Bristol Pyrometers—and remember Bristol offers a complete line of thermocouples and pyrometer accessories. The Bristol Company, 106 Bristol Road, Waterbury 20, Conn. *T.M. Reg. U.S. Pat. Off. 9.9

BRISTOL... for improved production through measurement and control

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS


Two 36-KW Controlled Atmosphere Belt Conveyor Furnaces used to heat treat radio tube parts.
• Belt Width — 12"
• Heating Chamber Length — 36"
• Variable Speed Drive — 3" to 24" per minute

Hypothetical 268,600-barrel oil storage tank 200 feet in diameter by 48 feet high. When designed in USS "T-1" Steel, plate thickness and weight are cut more than 50% with a total erected saving of $14,000.

Design Advantages of USS "T-1" Steel

The following thickness and cost figures result from comparing *two* designs for the tank—one using ASTM A283 structural carbon steel following API Standards, the other using USS "T-1" Steel at a higher design stress than permitted by API. Note, that although a higher unit stress is used with "T-1" Steel, an even higher safety factor on yield strength is obtained.

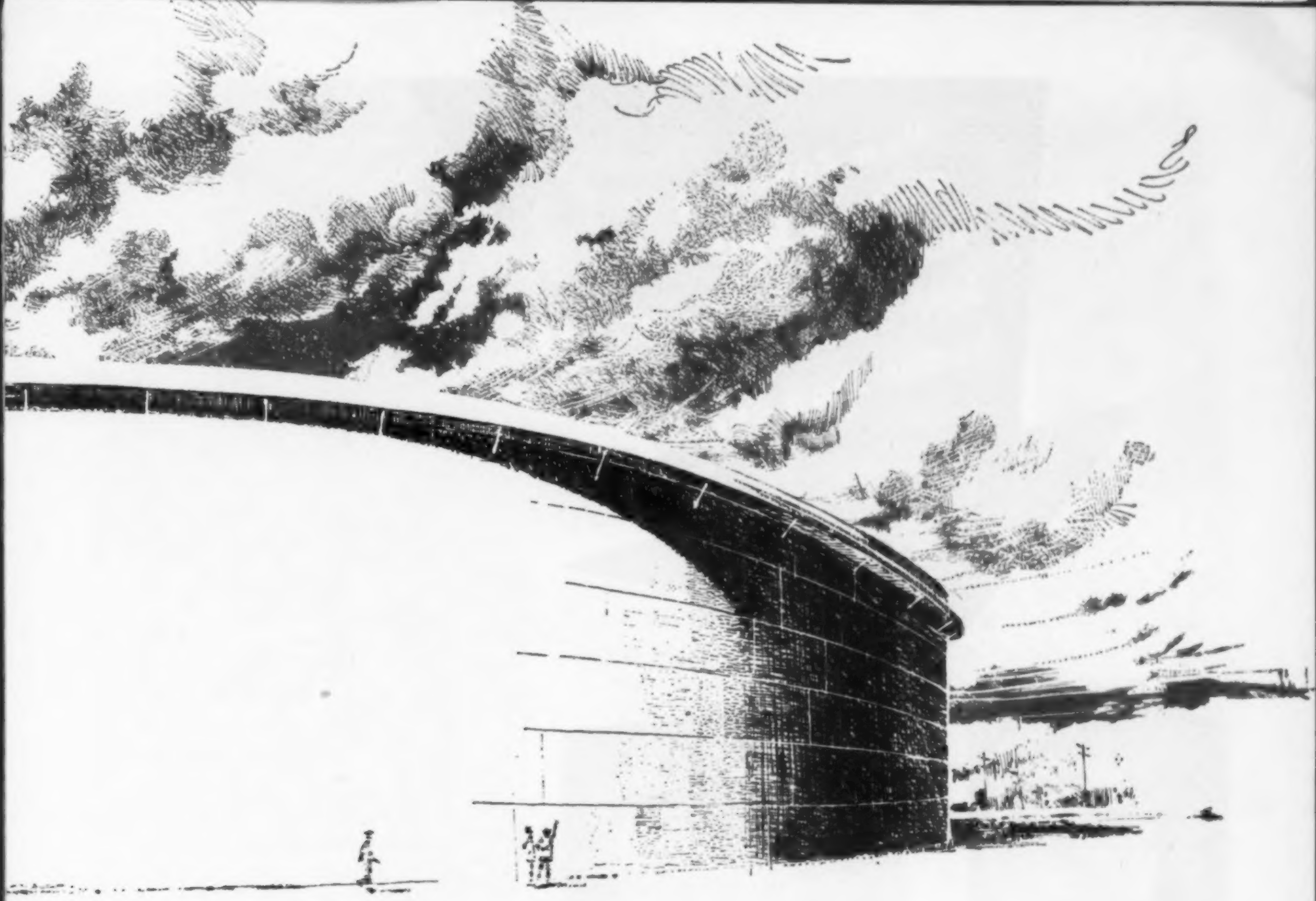
	USS "T-1" STEEL	ASTM A283 Carbon Steel
Yield Strength	100,000 psi	30,000 psi
Design Stress	50,000 psi	21,000 psi
Joint Efficiency	0.85	0.85
Working Stress	42,500 psi	17,850
Factor of Safety on Yield Strength	2.44	1.68

PLATE THICKNESSES COMPARED

	USS "T-1" STEEL	ASTM A283 Carbon Steel
Course No. 1	0.59"	1.37"
Course No. 2	0.49"	1.14"
Course No. 3	0.39"	0.91"
Course No. 4	0.3125"	0.67"
Course No. 5	0.3125"	0.44"
Course No. 6	0.3125" (A283 Steel)	0.3125"

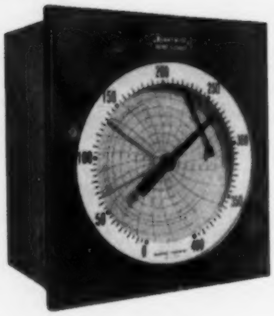
How USS "T-1" Steel can reduce costs (compared with A283 Steel)

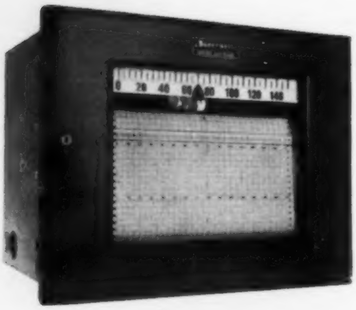
Material cost:	$4,400 more
but	
Fabricating cost:	$6,160 *less*
Freight cost:	$4,930 *less*
Erection cost:	$7,310 *less*
Overall savings with "T-1" Steel	$14,000

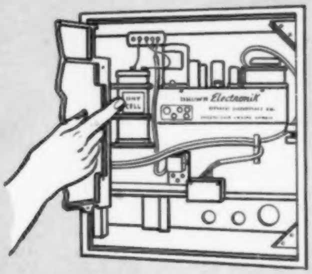


New Constant Voltage Unit makes *ElectroniK* instruments better than ever

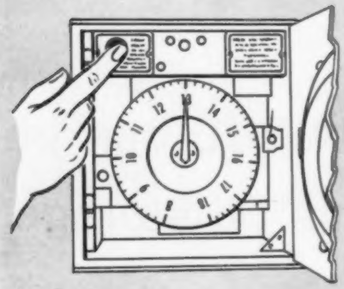
by eliminating these problems



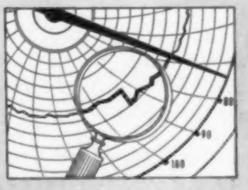




***No batteries* to replace . . . no recording or control deviation due to low battery voltage.**



***No button* to push on the instrument for standardization . . . no false readings because of failure to standardize.**



***No blanks or shifts* in the instrument's response to variables. You get complete continuity of recording and control.**

All new Precision Line *ElectroniK* circular and strip chart instruments have the new Honeywell Constant Voltage Unit that accurately regulates d-c reference supply to the measuring circuit. No more batteries, standard cells or standardizing mechanisms . . . and no more of the problems they pose.

The Constant Voltage Unit delivers a constant, rectified voltage from line supply. It uses dependable Zener diodes and a reliable ambient temperature compensator.

This latest improvement in *ElectroniK* instruments assures even greater dependability, and less maintenance, and is still another reason why *ElectroniK* instruments are your best value in measurement and control. Get full details from your nearby Honeywell field engineer. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.

Honeywell

H HONEYWELL *First in Control*

Finkl die blocks and forgings made of vacuum degassed steel*

*

REDUCE DOWNTIME

Finkl vacuum degassed steels result in die blocks, hot work die steels, and forgings with greater ductility and toughness. This means that size for size, and/or hardness for hardness, the degassed steel reduces the chances of breakage and excessive wear under severe operating conditions.

*

REDUCE MACHINING TIME

Finkl vacuum degassed steels are cleaner. About 50% of the nonmetallic inclusions have been removed. Machineability is improved, with higher lusters obtainable in die block impressions, if desired. Fewer tool regrinds are required.

*

ASSURE DELIVERY

Finkl vacuum degassed steels promote high density centers in large die blocks and forgings therefore reducing the possibility of late shipment because of ultrasonic rejection.

DIE BLOCKS · FORGINGS · HOT WORK STEELS · ELECTRIC FURNACE STEELS

F

For over 80 years Finkl has been producing top quality products. Now with the introduction of vacuum degassing of our electric furnace steels we have the most complete control of quality which enables us to offer the finest in die blocks, hot work die steels and flat die forgings. Call your Finkl representative.

A. Finkl & Sons Co.

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Warehouses in: CHICAGO · DETROIT · BOSTON · LOS ANGELES

To prevent corrosion and anchor paint on aluminum

ask Oakite

OVER 50 YEARS CLEANING EXPERIENCE • OVER 250 FIELD SERVICE MEN • OVER 160 MATERIALS

Protect aluminum at lowest unit cost with CHROMICOAT® conversion coating

Oakite CHROMICOAT is an economy any way you look at it: on the basis of price alone . . . on solution make-up and "mileage" . . . on the way it blocks corrosion and forms a perfect anchor for paint to keep your customers sold and satisfied.

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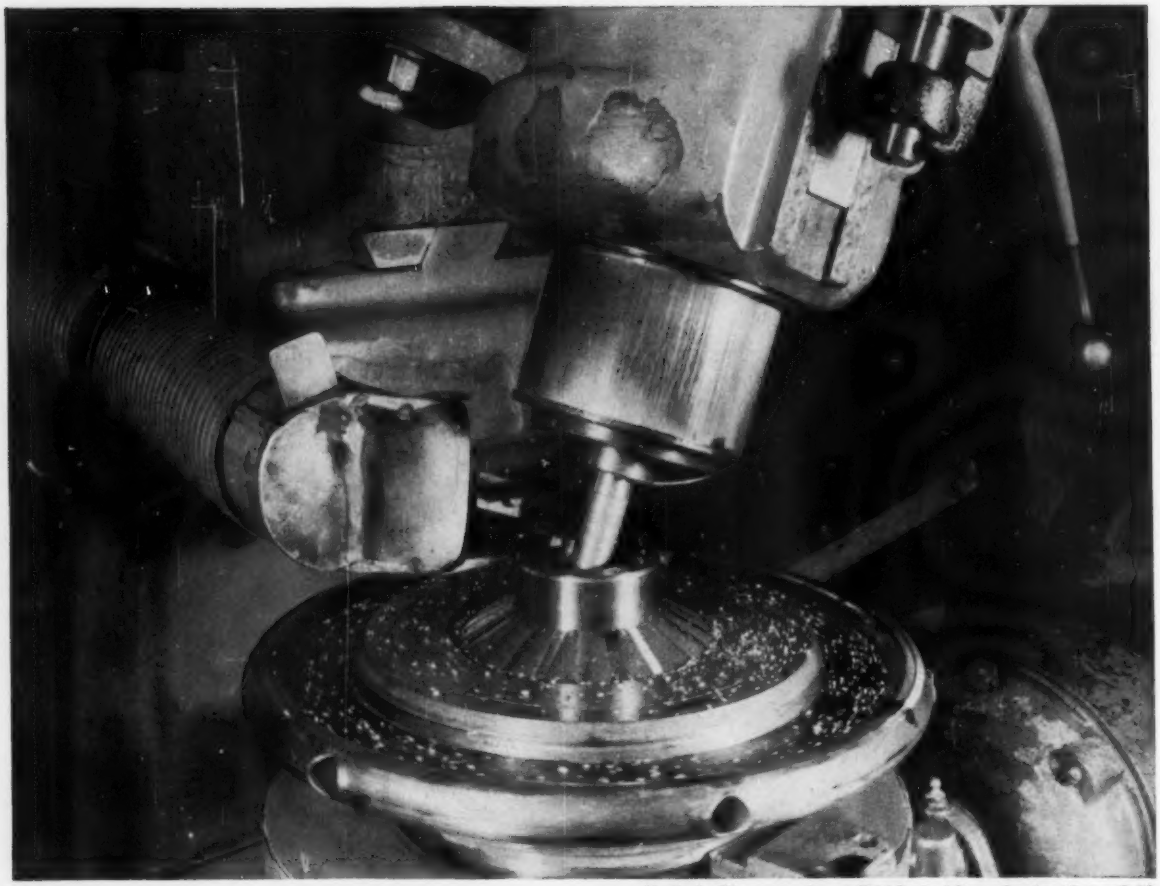
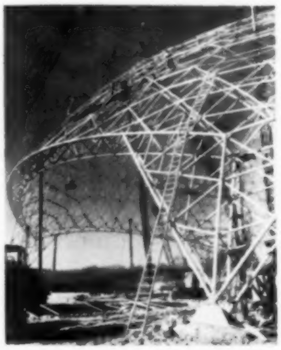
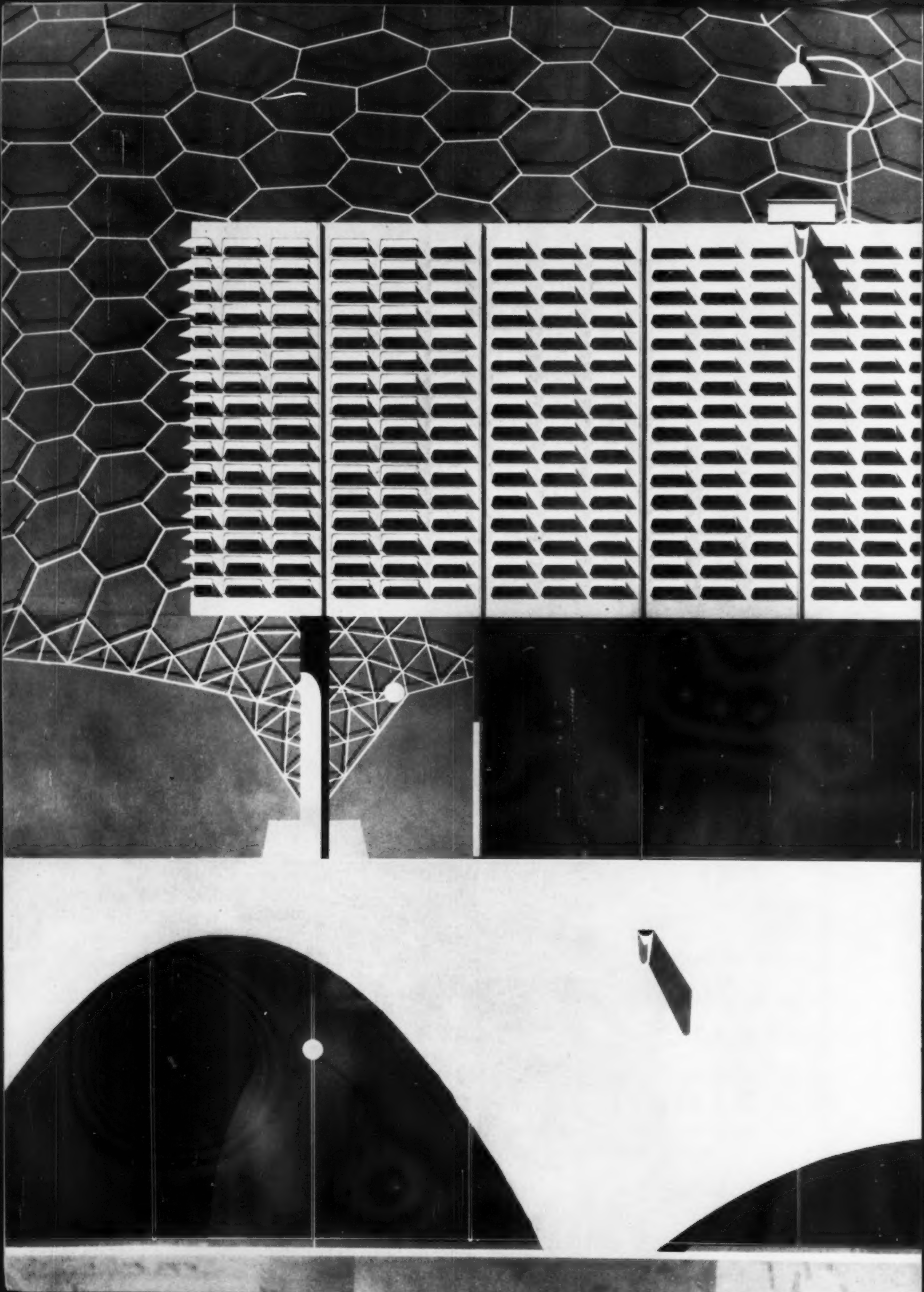


Vertical milling operation at Fluid Packed Pump Co., Los Nietos, Calif.

Moving Day for the American Society for Metals



Construction view shows make-up of double dome and its five pylons. The lower, more highly stressed members are 6-in. aluminum tubes with forged jointures; above, the tubing is 4 in. in diameter, joined by castings. Five miles of tubing and eight miles of 1¼-in. extruded tie rods were required.



WHEN, IN 1940, the American Society for Metals moved into its grand new quarters at 7301 Euclid Ave. in Cleveland, the management and staff felt they were fixed for good. The Society was 20 years old, its membership (recovering from a depression low) had gone up to 11,000 and the staff of 21 people found ample space in the big stone mansion and depended on the large coach house for warehousing and expansion.

Such was not to be. Another 20 years saw such an increase in activities associated with growth of membership to 30,250 and local staff to 105 that five separate buildings were occupied by A.S.M. activities. In fact the Board of Trustees recognized that new centralized headquarters would soon be essential, by making the first appropriation to a building fund in August of 1952. After a study of the comparative advantages of urban and suburban sites, the Board in 1955 decided to go suburban. No less than eight promising sites were examined in detail by a staff committee aided by outside experts in population trends, county planning, real estate and landscape architecture, and finally the Board in May of 1956 accepted the 100 beautiful wooded acres donated by our late National Secretary, Wm. H. Eisenman, a portion of his farm in Russell Township, east of Cleveland. It has been christened "Metals Park".

After about a year of unsuccessful search for an outstanding design, the Cleveland architect John Terence Kelly presented late in 1957 an ultra-modern plan for the building and its setting which was accepted by the Board of Trustees. Construction actually started in April of 1958. Following Mr. Eisenman's untimely death, A. P. Ford, sales manager of *Metal Progress*, was appointed coordinator of the project, which he pursued with such vigor that moving day was Aug. 22, 1959 – so closely on the heels of the builders that the completed building is still surrounded by construction equipment and satisfactory photographs could not be taken to illustrate this story.

As can be seen from the illustrations, the design of the new A.S.M. headquarters combines the utilitarian, the symbolic, and the aesthetic.

The utilitarian part is a three-level office building, a circular arc in plan, extending two-fifths of a circumference.

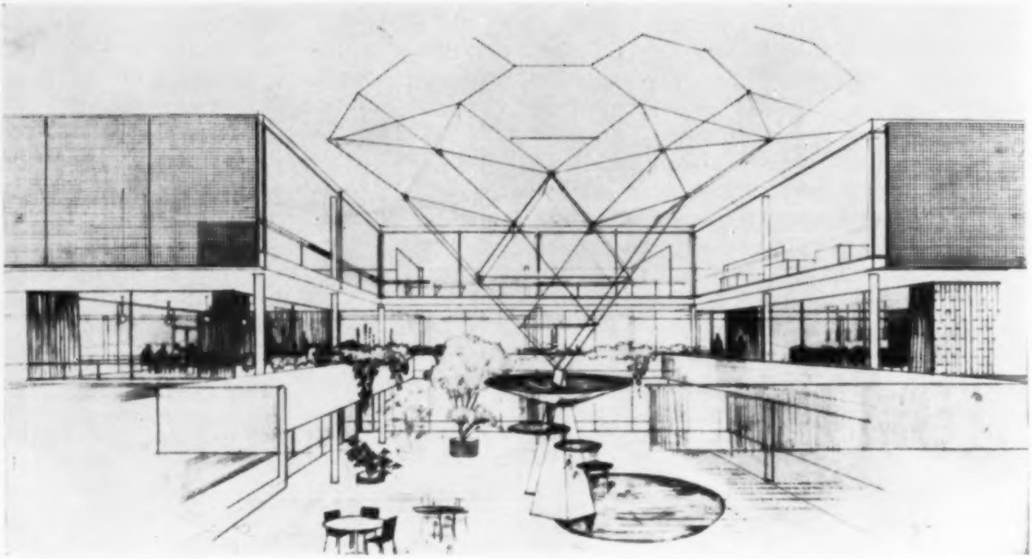
The symbolic element is a hemispherical dome, 250 ft. in diameter, 100 ft. high – an open lattice of aluminum tubing joined into hexagons – a striking symbol of man's mastery over the metals with which he works. The dome rests on five pylons, equally spaced at 72°; two of the five quintants embrace the office building.

The aesthetic aspect is achieved by building the structure and dome into the rural landscape, so to speak. The dome is open to the sky, the building is glass enclosed and views the surrounding woods and farm land; the rolling countryside merges into a circular piazza and "mineral garden" under the dome where monumental masses of our most important ores will be placed.

Driving into the entrance portico, the visitor will hardly know he is at a building, for he can look through the glass walls of the first floor in almost any direction and see the surrounding landscape. Flanking the entrance lobby on one

Architectural Rendering Visualizes Main Elements of the Monumental New A.S.M. Headquarters. An arched wall leads into the lower level; the other floors are glass enclosed; the top floor has an outside stainless screen on the sunny exposures; crowning it all is the soaring dome, open to the sky

Progress Photograph of Building Nearing Completion, View Looking East. For close-up of what the central portion will eventually look like, see the rendering on the next page



Architect's Sketch of Court in Lower Level. Stainless steel pyramids support space lattice pylon and a series of shallow water basins, fountain-like. On the lower level at this region is the dining room; on the middle level or main floor at left is a conference room and at right is the board room; on the top floor are offices for most of the staff. A stainless steel lattice shields the glass walls from the western sun

side is the library and on the other side an assembly room, the board room and executive offices. The floor above is more commodious, and houses the following main departments, end to end:

Expositions, in charge of C. L. Wells
Accounting, in charge of A. A. Hess
Sales and Advertising, in charge of A. P. Ford
Metal Progress Editorial, in charge of E. E. Thum
Metals Handbook, in charge of Taylor Lyman
Transactions, in charge of T. C. DuMond
Metallurgical Engineering Institute; in charge of A. deS. Brasunas

The floor below grade contains cafeteria and kitchen, drafting room, membership department, warehouse and heating plant.

A sincere effort has been made to use the modern metals and alloys as extensively as possible in this new national headquarters of the American Society for Metals. In addition to the indispensable structural and reinforcing steel and new enameled steel furniture throughout, stainless steel has been extensively used in a sun shield on the west side and ends of the second floor, in the entrance portico and doors on the first floor, for constructing the main stairway, and in kitchen and cafeteria equipment. Copper, also, is used throughout the heating and electrical system, and brass and bronze on balustrades, elevator and its doors, and innumerable places on interior trim. In addition to the dome, aluminum finds itself in all window frames. There is titanium furniture in the board room. Undoubtedly as time passes and opportunity presents, many metallic objects of art will further embellish the interior.

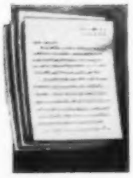
Of course all members of the American Society for Metals are most cordially invited to inspect their new building at any time. Being out in the country, it requires an automobile for transportation. If you are in downtown Cleveland, drive to the end of the Van Aken branch of the Shaker Rapid Transit line, thence out Kinsman Road (Route 422) to where Route 87 branches off to the left, thence east on 87 to the site. (You'll see the dome from miles away!)

If you're coming from the East on Route 20, after passing Mentor branch off to the south on Route 306, go as far as its intersection with Route 87 (Russell), thence east to the site.

If you're traveling on the Ohio Turnpike in either direction, leave the pike at Interchange No. 13 at Streetsboro, proceed on Route 43 to its intersection with 306, thence north to Russell and turn east on Route 87 to the site.

We'll be expecting you! The new address is

American Society for Metals
Metals Park
Novelty, Ohio
Phone: JOrdan 4-2271



Critical Points

By the EDITORS

The Dilemma of Materials

In a speech at the official opening of Republic Steel Corp.'s new Research Center in Cleveland recently, T. Keith Glennan, the nation's space chief, remarked that the first United States nuclear airplane ought to be flying now, considering the vast sums already spent. "We have already spent $900 million for a nuclear plane," said Dr. Glennan. "If we had put one tenth of this into a sound program for the materials we need, 10 years ago, we would have the airplane flying rather than in development."

Dr. Glennan emphasized that he didn't wish to criticize the spending program but rather to point out that it should teach the nation "a lesson" in spending in the space age. "We tend to get into hardware before we have a full understanding of all the problems," he further commented.

Dr. Glennan's remarks bring to mind comments we recall being made by John T. Norton, professor of metallurgy at Massachusetts Institute of Technology, some two years ago at an A.I.M.E. Conference on High-Temperature Materials. In discussing progress in cermets (or lack of progress!), Dr. Norton stated: "We have concentrated on the problem of making hardware, and as a result we have neither the kind of hardware we want nor the understanding of how to get it. If we now concentrate on the understanding, I believe a superior brand of hardware will be an automatic consequence."

Certainly, these observations re-emphasize the need for developing more basic knowledge of materials – something we have been hearing more and more about recently. True, much of the accelerated need for discovery and application of new materials can be traced to the insatiable demand of our armed services for new weapons. However, with increasing economic pressure in the metals goods industry, producers of "everyday" products are finding that materials must be tailored more closely to design, manufacture and service requirements. Here, too, basic work has a way of paying off in the long run. Manufacturers are realizing that new devices and improvements in the old ones result from more and more knowledge of the materials with which they work.

There is an important role for the metallurgist in the development of the science of materials because he already appreciates the important relationship between structure and properties so important to an understanding of the fundamental problems of materials engineering. Today's challenge in materials offers the metallurgist an opportunity to expand his interests and to broaden the scope of his activities. In his speech, Dr. Glennan also suggested, "The time has come to change our concept of the metallurgical industries . . . Instead of thinking of the steel industry or the aluminum industry, we should consider them all together as interlocking segments of our dynamic materials industry. Only then can the vast potential of industry in creative technology serve the varied needs of advanced design." Metallurgists of our country could supply the thinking which might start us on the way toward the understanding we must have to work out a solution to our materials dilemma.

Austenitic "Cold Working" for Ultra High Strength

By D. J. SCHMATZ,
J. C. SHYNE
and V. F. ZACKAY*

Need for materials with higher strength-to-weight ratio has motivated the search for new heat treating processes for steels. Key to a technique studied at Ford is plastic deformation in the austenitic "bay" of the TTT-diagram between pearlite and bainite, then quenching to prevent transformation to nonmartensitic products. (J26p, Q27; AY)

A DECADE AGO, martensitic steel of S.A.E. 4340 type, oil quenched and tempered at 900° F. to a tensile strength of about 200,000 psi., was acceptable to the aircraft industry. The high tempering temperature was used to obtain specified elongation and impact toughness. Since then, the development of ultra-high-strength steels has been based on tempering temperatures below the so-called "500° F. embrittlement range", or on modification of composition to permit tempering in the normally avoided 500° F. range. By changes in composition and heat treatment, a series of steels was made which combine good ductility with tensile strengths near 300,000 psi.

A promising hardening technique was suggested by the Dutch scientists E. M. H. Lips and H. Van Zuilen (*Metal Progress*, August 1954, p. 103). They reported unusually high tensile strength for a steel of high hardenability which was heat treated to a metastable austenitic condition, severely deformed between its recrystallization and martensitic transformation temperatures, and then transformed by cooling to room temperature.

Work at the Ford Scientific Laboratory has confirmed the feasibility of improving steel by this sort of thermal-mechanical processing. A similar technique has been developed by Schmatz and Zackay† called the "Ausform" process‡. It includes austenitizing a steel, quenching it to the austenitic "bay" between pearlite and bainite where it is plastically deformed, then quenching it to room temperature.

In Ausforming we minimize the decomposition of austenite to nonmartensitic products, which may occur in the Lips-Van Zuilen process, by choosing steels with high hardenability, and limiting the temperature range for deformation to the austenitic bay from which the steel is quenched to martensite. Essential features are schematically illustrated in Fig. 1. Microstructure, degree of deformation, and carbon content are significant variables.

The nominal compositions of steels examined were 0.48% C (steel 48) and 0.63% C (steel 63), with 3 Cr, 1.5 Ni, 0.75 Mn, 0.5 Mo and 1.5 Si.

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*Scientific Laboratory, Ford Motor Co., Dearborn, Mich.

†"Mechanical Properties of Deformed Metastable Austenitic Ultra-High-Strength Steel", by D. J. Schmatz and V. F. Zackay, *Transactions* ⊕, Vol. 51, 1959, p. 476.

‡Registered trademark of Ford Motor Co.

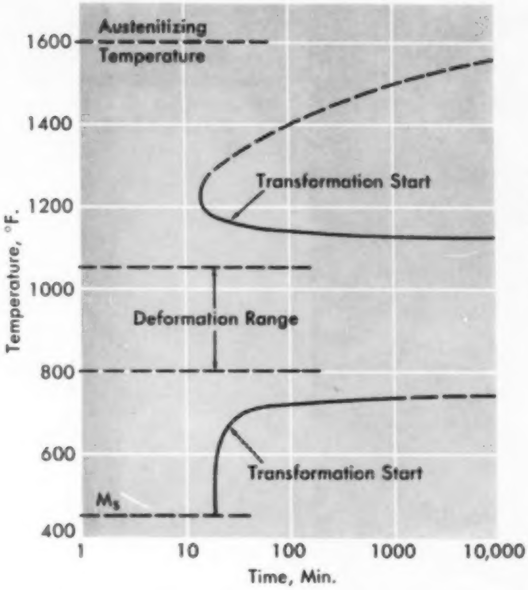


Fig. 1 – TTT-Diagram for Steel Showing Essential Features of Ausforming – Austenitizing and Quenching to the Metastable Austentic Zone Where the Steel Is Deformed

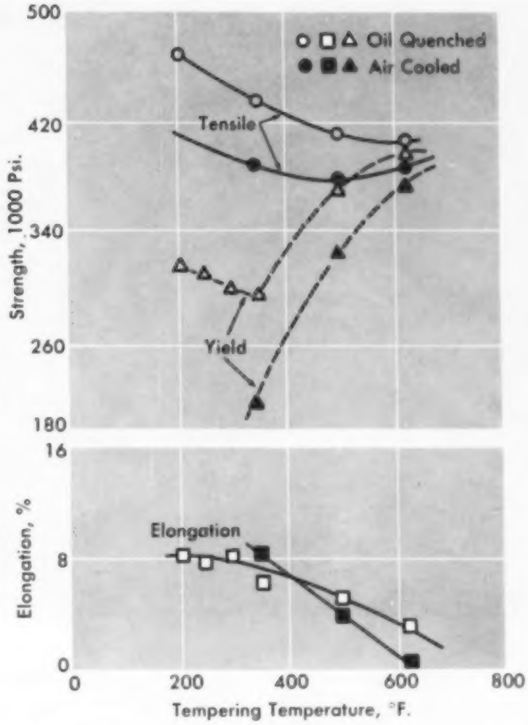


Fig. 2 – Effect of Nonmartensitic Decomposition Products on the Mechanical Properties of Ausformed Steel 63 (3 Cr, 1.5 Ni, 0.75 Mn, 0.5 Mo, 1.5 Si, 0.63 C), 90% Deformed. The air cooled steel contained some ferrite-carbide aggregates; the oil quenched steel was martensitic

Present indications are that nonmartensitic transformation products are detrimental. The mechanical properties of steel 63 (deformed 90%) plotted against tempering temperature are shown in Fig. 2. One group of specimens was immediately oil quenched after deformation, while the others were air cooled to permit some nonmartensitic decomposition. The tensile and yield strengths of the steel containing nonmartensitic products were lower than its oil quenched counterpart. Ductility of both steels was found to be comparable.

Differences in microstructure suggest the reason for the superior strength of the oil quenched steel. It was essentially martensitic; however, the air cooled structure of steel 63, shown in Fig. 3, contained extensive nonmartensitic products on slip bands and on twin interfaces. These delineate the extent of metal flow, and their curved and intricate pattern indicates the absence of recrystallization in the severely deformed steels.

Process Refines Microstructure

Steels which have been Ausformed contain a refined microstructure. Electron photomicrographs of a carbon steel are shown in Fig. 4 (no austenitic deformation at left; deformed 93% at right). Both samples were oil quenched and tempered at 400° F. for 1 hr. The largest martensite plate shown in the electron micrograph of the deformed steel is 1½ microns long. Martensite plates in the same steel, undeformed, measured about 3½ microns.

A relationship exists between the yield and fracture stresses and the size and distribution of microconstituents in Ausformed steels. The microconstituent size is dependent in turn upon the prior austenite grain size and the degree of deformation.

Austenitic Deformation Increases Strength

Preliminary observations show that a critical amount of deformation is required for a significant increase in mechanical properties. Since large amounts of deformation are necessary for significant improvement in properties, and nonmartensitic products should be avoided, both deformation temperature and composition are critical. Optimum properties are obtained only by deforming in the temperature range of an

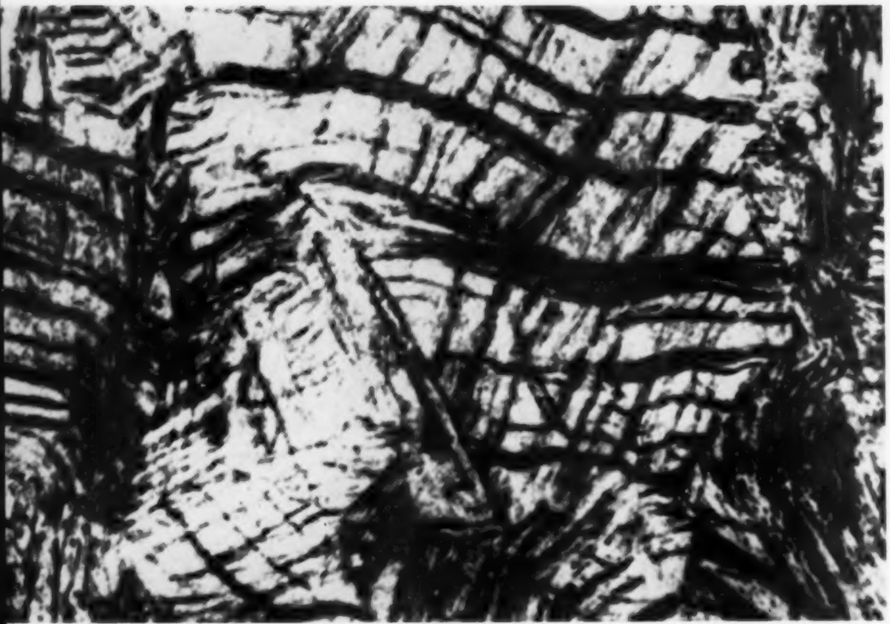
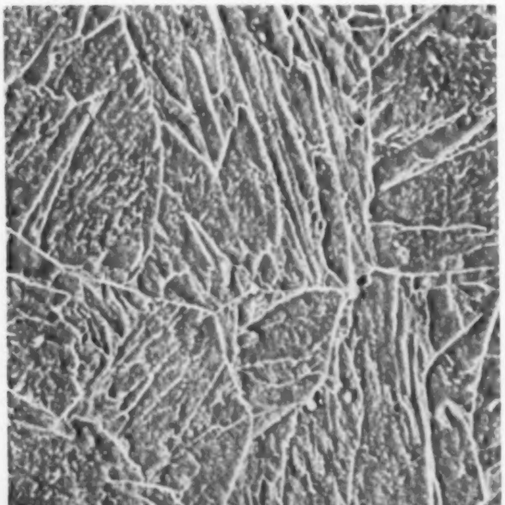
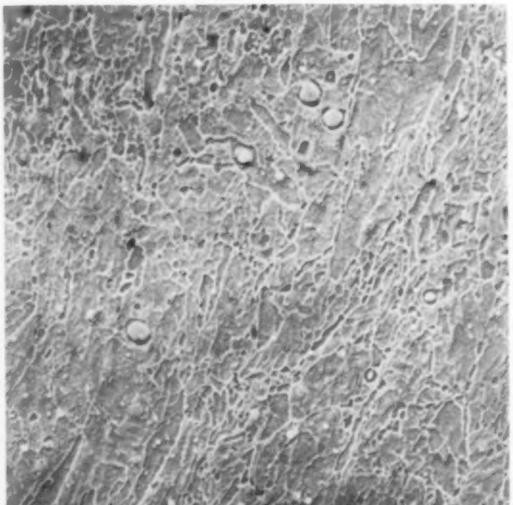


Fig. 3 – Photomicrograph of Steel 63 (0.63% C) Deformed 90% in the Metastable Austenitic Condition and Air Cooled to Permit Formation of Nonmartensitic Products. 2000 ×

Fig. 4 – Electron Micros of a 0.40% C Steel. Left – Oil quenched from the austenitizing temperature and tempered 1 hr. at 400° F. Right – Ausformed (93% reduction) and tempered for 1 hr. at 400° F. Deformation has refined the structure. 15,000 ×





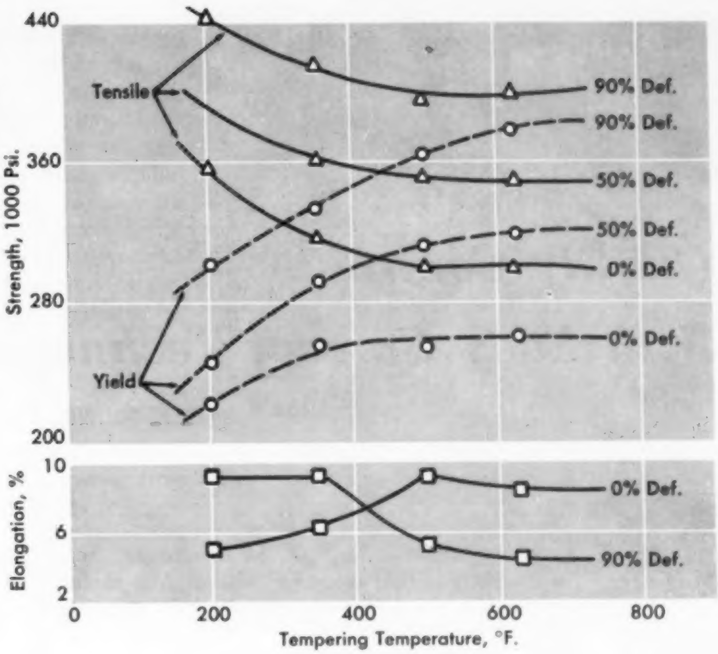


Fig 5 – Effect of Austenitic Deformation and Tempering Temperature on Mechanical Properties of Steel 48 (3 Cr, 1.5 Ni, 0.75 Mn, 0.5 Mo, 1.5 Si, 0.48 C)

austenitic bay. The extent of the austenitic bay is determined by the steel composition.

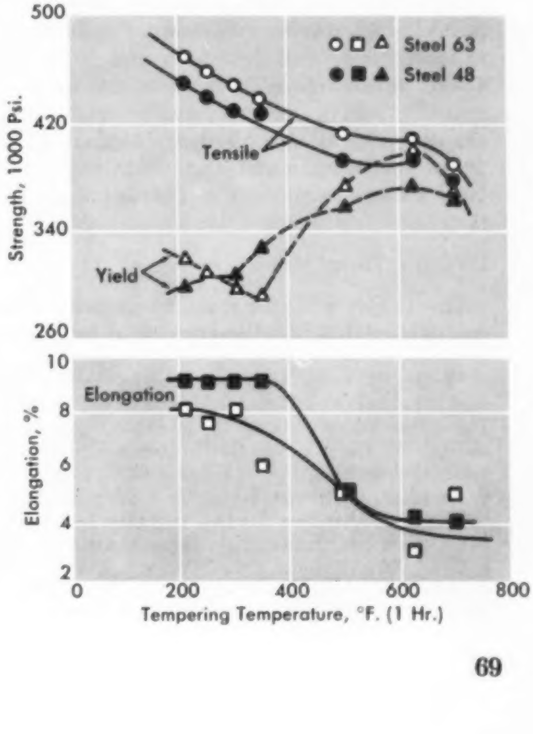
Steel 48 was deformed 0, 50 and 90% and oil quenched. Its yield and tensile strength and elongation are shown as functions of tempering temperature in Fig. 5. Large increases in both the yield and tensile strength occurred after both 50 and 90% reduction. The data for the 0 and 50% deformations were taken from specimens ¼ in. in diameter; however, the smaller finished bar of the 90% deformed material necessitated use of a specimen with a reduced section ⅛ in. in diameter. For this reason, the comparative elongation values should be regarded as qualitative. In general, best ductility was obtained at a low tempering temperature and high rate of deformation.

Interstitial Carbon Important

Hardness and strength of martensite are known to be functions of the interstitial carbon content. The effects of carbon on the mechanical properties of steels 48 and 63 deformed 90% are illustrated in Fig. 6. The higher-carbon steel exhibited a greater strength over the complete tempering range. An ultimate tensile strength of 464,000 psi. was observed for this steel after a 212° F. temper. Yield strength rose sharply and uniformly above 350° F. to about 400,000 psi. after tempering at 600° F.

The elongation of steel 48 was generally greater than that of steel 63. This trend in rising strength and falling ductility with increasing carbon content was similar to that observed in conventionally heat treated martensitic steels.

Fig. 6 – Effect of Carbon on Tempered Steels Which Were Deformed 90% While in the Metastable Austenitic Condition



Quality Control With Eddy Current Techniques

*By C. E. QUINN**

A new inspection instrument, the Laminagage, readily measures the thickness of thin gages and plates. Also useful for locating fine cracks, this versatile tester employs plug-in coils and several types of probes. (S13h, S14h, 1-53)

ALTHOUGH EDDY CURRENTS have been used to determine coating gages and surface conditions for only a short time, much of the theory is already known. This knowledge has been applied in designing the Laminagage (Fig. 1), a device which measures thicknesses under 0.010 in. and detects surface cracks and inclusions. Operating through eddy currents, the machine senses differing surface conditions through changes in impedance. Frequencies from 0.1 to 20 megacycles are used. The Laminagage† provides a fast, accurate and inexpensive means for the nondestructive inspection of production parts.

How the Tester Works

The carrier wave at radio frequency is frequency-modulated at the power-line frequency rate. This modulated signal is coupled to the probe, and the resulting field at the probe coil penetrates the surface being tested. Penetration depth depends on conductivity and permeability of the conductor, power input and proximity of the probe coil, and the operating frequency. When applied to a metallic surface, the probe coil senses a change in impedance because there are current losses in the conductor. This change is also reflected into the driving oscillator which produces a signal pulse relative to the start of each sweep cycle. After pulse amplification, additional circuitry provides an average current which is indicated on a meter. When energy flux of the proper frequency penetrates into the conductor, and the power input and spacing of the work coil are held constant, variations in the conductor thickness will change the average current and corresponding meter reading. Through appropriate standards, the meter may be calibrated in thickness.

Measuring Thicknesses

An overlay, according to our definition, consists of a thin coating on a base metal of considerably greater thickness. If the coating conducts, it must have a different conductivity or permeabil-

*Senior Research Engineer, Physics Dept., Research Laboratories, General Motors Corp., Detroit.
The author wishes to thank the inventors, R. L. Saur and E. A. Hanysz, for their cooperation and to acknowledge the aid of J. Felice and C. Glover in this work.

†This tester has been licensed to Gulton Industries, 212 Durham, Metuchen, N.J.; Branson Instruments, Inc., 27 Brown House Rd., Stamford, Conn.; and Photocon Research Products, 421 N. Altadena Dr., Pasadena, Calif.

ity (or both) from the base metal. Frequency, coil spacing, and power input must also be adjusted so the field can penetrate the top coating and enter the base. However, if the coating is nonconductive, significant penetration into the base is not required. In fact, it is often undesirable since less penetration of the base provides increased sensitivity to thickness variations. In both instances, surface roughness affects the thickness reading because the induced eddy currents are distorted. Although bothersome for thickness measurement, this provides a very efficient method for crack detection, as will be discussed later.

Conducting overlays must be measured empirically to find the optimum frequency and coil spacing which can best isolate the coating from the base. A typical fixture for a probe coil used to measure copper plating is shown in Fig. 2. Base material was cold rolled steel tubing; copper plate was 0.0003 to 0.0006 in.

A problem recently solved with the lower frequencies is measuring the thickness of copper on zinc. Copper thickness varied from about 0.0005 to 0.002 in. Conductivities and permeabilities of this combination are very close, but a frequency of 200 kc. per sec. can measure the copper successfully.

Nonconducting overlays on cold rolled steel can usually be measured successfully with the Laminagage. The tester gives very satisfactory results on nonconductors such as paint, plastic, and porcelainized coatings up to 0.0075 in. An area of the bare metal must be accessible to establish a base reference. Calibration for nonconductors can easily be made by using thin Mylar or other insulator of known thickness between the probe and the base metal. A good rule of thumb is to employ the lowest frequency possible, taking base metal, coating thickness and sensitivity into consideration. This helps to lessen the effects of slight material curvatures and chemical variations. However, if too low a frequency is employed on thin base materials (0.001 to 0.02 in.), the overlay reading may be in error due to sensitivity to the thickness of the base. If the base material gives nonuniform readings at high frequencies, sensitivity must be sacrificed in favor of a lower frequency.

In general, very thin layers are measured at frequencies higher than 600 kc. per sec. For example, an anodized coating on aluminum usually varies from 0.0001 to 0.005 in. A frequency of 10 to 20 megacycles per sec. is required for this measurement.

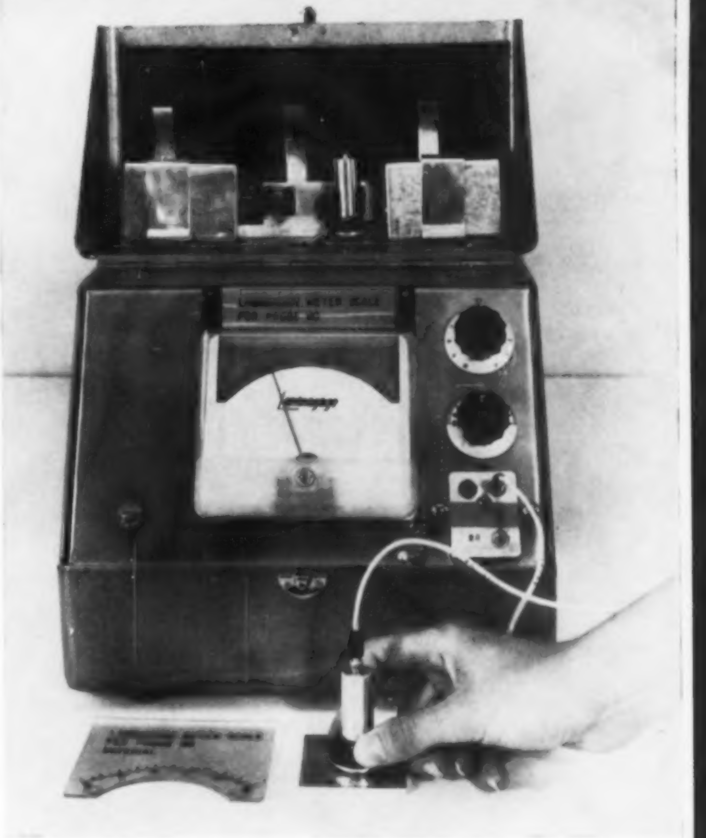


Fig. 1 – Using the Tester for Measuring Thickness of Flat Surfaces. Plug-in coils range from 0.1 to 20 megacycles per sec.; this instrument can thus be easily adapted to inspect a wide variety of plates and base metals

Thin metal foils, ranging from 0.001 to 0.010 in., can also be measured. This may be done by flattening magnetic foils on a nonmetallic base, or nonmagnetic foils on a steel base. (In the latter instance, sensitivity is greatly increased.) Frequencies between 0.3 and 2 megacycles per sec. are used depending on the thickness range and accuracy desired.

Magnetic materials, with their higher permeability and lower conductivity, offer much higher sensitivity to eddy current inspection. However, their wider chemical and conductivity variations (and residual magnetism) may mask overlay thickness indications.

Measuring Multiplates

As stated above, the thickness of a conducting overlay on a base metal may be measured providing there is sufficient difference between conductivities or permeabilities or both. In measuring multiple thicknesses, this factor is used to isolate the top and second coatings from the base metal. Such an application is the meas-

Fig. 2 – Special Clamp Holds Coil in Position While Measuring Copper Plating on Steel Tubing. Other probes and coils can be selected to measure multiple coatings and detect surface defects

urement of nickel over copper on a zinc base. The nickel, which is measured first at 600 kc., affects the copper measurement. Copper and zinc, being close in conductivity and permeability, look the same to the probe at 600 kc. per sec. Consequently, the hidden copper is measured at a lower frequency, 200 kc. per sec.

Measurements of this type require accurate foil standards for basic calibration. Tests to date indicate that all triple plate combinations will not lend themselves to this procedure. For instance, in a plating buildup of cold rolled steel covered with copper and then nickel, a frequency low enough to measure the nickel thickness will also penetrate the copper and enter the steel base. This means that the probe will recognize copper or nickel thickness variations, and readings will be in error.

Detecting Surface Cracks

Since its inception, the Laminagage has been recognized as an excellent locator of surface cracks. Fine defects, visible only with a 50-power microscope, may be easily detected. The use of radio frequencies and a probe coil with a small diameter greatly increases the sensitivity to small cracks but necessitates mechanical scanning of the surface. When the probe passes over a crack, the induced flux is distorted, causing a change in coil impedance which is sensed by the Laminagage circuit. This change can be indicated on a meter, or it may furnish an output pulse to trigger sorting equipment.

Any metal surface, from rough castings to machined parts, may be scanned in this manner. Frequencies from 600 kc. per sec. (for coarse-grained castings) to 20 megacycles per sec. (for machined parts with fine grain) are used. Successful use of the higher frequencies depends on surface uniformity as well as other items such as chemistry, residual magnetism, grain size and hardness. Scanning rate depends on the surface condition and type of indication desired. Figure 3 shows the meter indication method for inspecting spark plug shells at a slow speed. For scanning (ranging from 4 to 12 in. per sec. as required on automated lines), electronic circuits provide automatic sorting.

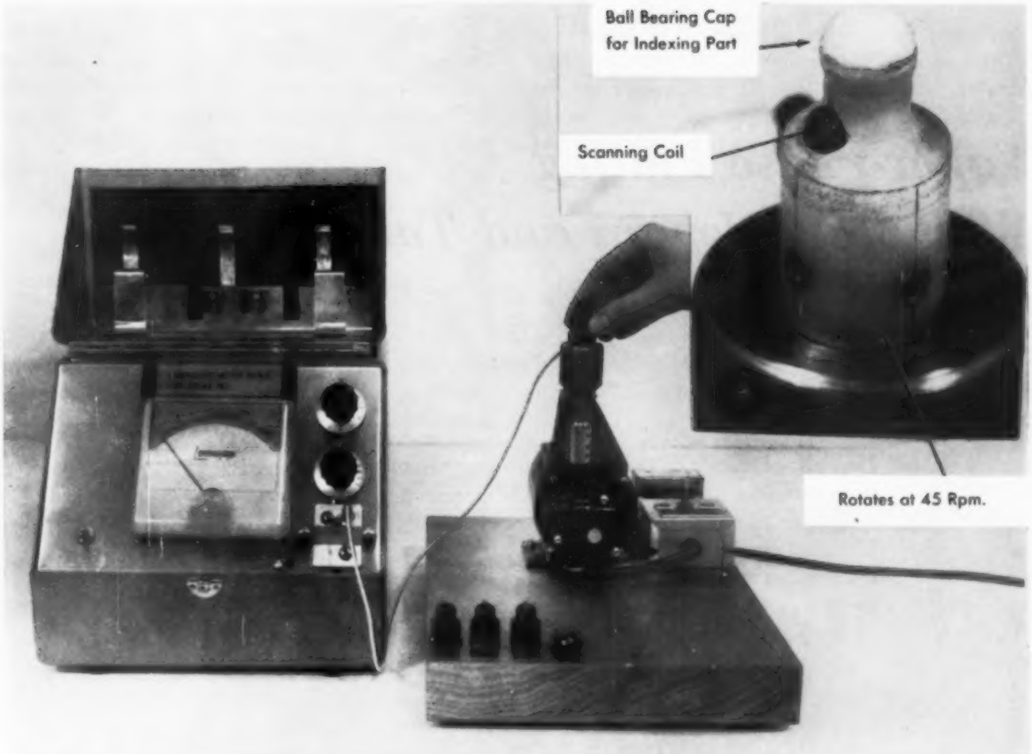


Fig. 3 – Scanning the I.D. of an Extruded Shell. Inset shows spring-biased scanning coil on sapphire rod mounted in 45-rpm. fixture

For successful work, the probe must be correctly designed. A hand-held probe should, of course, be easy to handle; it must also provide accurate, reproducible readings. The probe in Fig. 1 was designed with this in mind. The one-piece handle and foot section has three nylon ball feet which sit on an area less than $3/4 \times 3/4$ in. Spring loaded, the coil insert keeps the adjustable sapphire touching the test sample. The coil is pancake-wound of either wire or tape to suit the sensitivity requirement. Adjustment of the sapphire provides control of sensitivity and minimizes effects of slight curvatures.

Some applications – crack detection, for example – do not require spring-loaded probes. When inspecting for cracks in rough castings, a probe having a teflon bearing surface and a slightly recessed coil to prevent winding damage has been successful. In scanning rotating parts for crack detection, curved pancake coils or small multilayer solenoids are used. They can be spring loaded or fixed depending on the concentricity of the part.

To sum up, eddy-current testing at high frequencies has many advantages and disadvantages. The method is useful on almost all metals and nonconducting overlays, and can measure coating thickness to a ten-thousandth of an inch. It is responsive to surface conditions, and penetration can be controlled to improve sensitivity. In fact the probe does not always need to touch the work. Since the method can be used on either inside or outside diameters of tubes and requires no special training, it is useful in mass-production applications.

There are some drawbacks, of course. Sensitivity of the method, though helpful in many respects, makes adjustment quite difficult. The probe coil must be aligned precisely, and the instrument is sensitive to variations in chemistry, stress, and hardness. Due to the method's low depth of penetration, special probes are required for specific areas and the test area must have the same contour as the standards for calibration.

Despite these problems, the Laminagage has proven to be a most useful instrument. Its wide frequency range and plug-in circuitry make it extremely flexible for measuring overlays and detecting cracks.

Vapor-Phase Plating With Molybdenum and Tungsten

*By H. W. SCHULTZE**

Deposits of metals or their refractory compounds are produced from chlorides and carbonyls of molybdenum and tungsten at temperatures considerably below the melting point of the metals. Coatings can be produced on a variety of metals: ceramics, glass, refractories and graphite. Interest in the process is spurred by today's technological needs and commercial availability of the plating chemicals. (L25; *Mo, W*)

INTEREST TODAY in vapor-phase deposition of molybdenum and tungsten is growing – and for good reason. Where fabrication from massive metal is difficult and not economical, this new technique may hold the answer. Even more important for missile and space applications is the weight saving possible by applying coatings of these metals on low-density refractories or graphite. The technology of vapor-phase deposition has advanced to the point where industry can now evaluate its application to specific problems. Enough is known about the process variables, characteristics of deposits, and the nature of required base materials to recognize areas of potential application.

The use of vapor-phase deposition may sometimes be necessary because there is no alternative. For example, there is no successful method for the electrodeposition of pure molybdenum or tungsten. In other instances, vapor plating gives a composite part which may offer advantages not obtainable with either material alone. The processes also yield pure molybdenum and tungsten metals without going through oxide phases.

Scope of Process

Vapor-phase deposition results from the chemical reaction of a gaseous molybdenum or tungsten compound at a heated surface. The process is reasonably versatile, permitting the deposition of the metals or their refractory compounds (borides, nitrides, carbides, silicides) on outer and inner surfaces and irregular surfaces, generally without weakening the base material.

Both conductive and nonconductive materials can be coated without liquid or gaseous entrapment. Thickness of coatings can be controlled and deposits are adherent, stable, and for the metal coatings, ductile.†

Molybdenum and tungsten have been successfully deposited on copper, nickel, cobalt, rho-

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†Outstanding contributions to an understanding of carbonyl decomposition were made by Lander and Germer of Bell Laboratories, and of hydrogen reduction of molybdenum pentachloride by Wulff and co-workers at Massachusetts Institute of Technology. The commercial aspects of carbonyl

dium, alloy steels, iron, graphite, porcelain, alumina, fused silica, silicon carbide, uranium dioxide, Pyrex glass, glass fibers, sintered carbide, Inconel and molybdenum screening, and tile. This variety of base materials (and no doubt there are others) presents many product possibilities.

Applications for Vapor Plating

Some items on which molybdenum and tungsten might be vapor deposited are rocket nozzles, combustion chamber linings, X-ray tube targets, die blocks and cores, crucibles, gas turbine blades, valve and cylinder linings, small thermocouple wells, resistance thermometers, bolometers, and transistors. For certain corrosion resistance uses, it may be desirable to deposit molybdenum and tungsten on chemical ware and piping. Molybdenum's good nuclear properties may make it useful for cladding reactor components.

Techniques have been devised for continuous coating of wire, rod, strip, and tubing with high-purity molybdenum and tungsten. A molybdenum coating, 0.0005 to 0.0009 in. thick, can be deposited on copper wire at a rate of 0.0001 to 0.0002 in. per min. in lengths up to 1000 ft. The coating is ductile enough for spooling the wire.

Refractory and ceramic particles coated with molybdenum or tungsten may prove useful as catalysts for chemical processing. Compacting such particles may also produce cermets with greater strength, improved heat transfer and better thermal and mechanical shock resistance.

Electronic Applications

An interesting application study was made by Bell Laboratories on continuous coating of copper magnetron rings, 0.8 cm. I.D. Purpose of the 0.0002-in. molybdenum coating was to dissipate the heat generated by electron bombardment and to provide strength at high temperatures. The initial bond to the copper was made at 800° C. (1475° F.) and plating was continued at 650° C. (1200° F) in wet hydrogen. The hardness of the deposited molybdenum was Vickers 220. This coating was deposited in 4 min.

Molybdenum and tungsten deposits containing carbon and carbides possess wear properties which might make them well suited for bearings, dies, rolls, gages, and a variety of tools. Modified surfaces containing molybdenum disulphide may be useful for semiconductors or lubricants. Electrical contacts can be coated with tungsten carbide to prevent arcing. Electrodes or grids coated with molybdenum carbide improve heat resistance and are poor electron emitters. It is quite possible that equipment could be built to continuously coat such small electronic and elec-

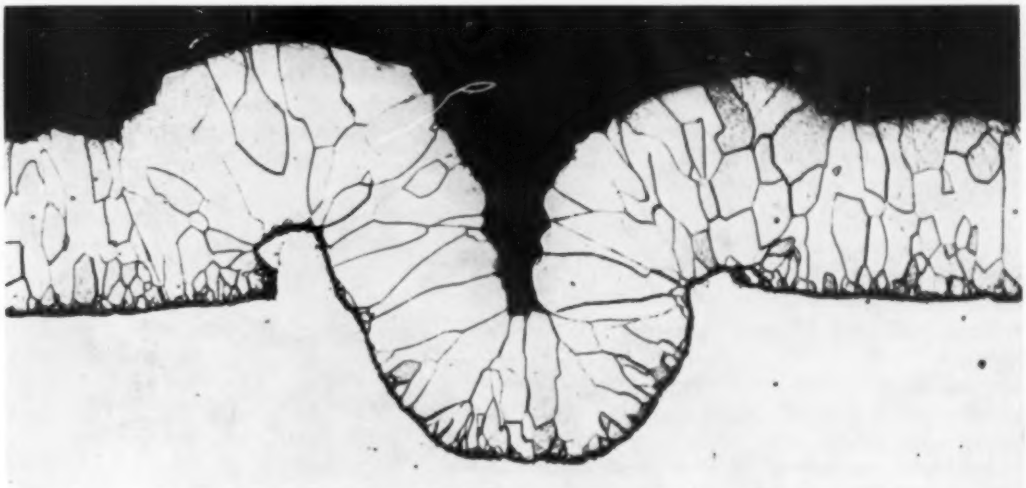


Fig. 1 — Molybdenum Metal Vapor Deposited on Inconel. Note how the deposit follows the surface contour. 125×. (Courtesy Massachusetts Institute of Technology)

decomposition have been studied by Commonwealth Engineering Co. and hydrogen reduction by National Research Corp. Contributions to knowledge of both processes have been made by Battelle Memorial Institute. Work is still being carried on by these groups and by a newcomer, Alloyd Research Corp.

trical components. Ultra-high-purity molybdenum metal is being made by hydrogen reduction of the chloride and equipment is being built to make metallic tungsten this way.

Co-Deposition of Alloys

An intriguing possibility is the simultaneous reduction of the plating gases to produce alloys. Alloys containing up to 18 to 19% W in molybdenum have been reported. Actually these deposits may not be true alloys, but rather intimate mixtures of molybdenum and tungsten which may have unique properties. Addition of other metals to molybdenum in even small quantities by simultaneous vapor-phase deposition may widen applications for this metal.

Processes for Vapor Plating

Two processes are available – thermal decomposition or pyrolysis of the volatile carbonyl and hydrogen reduction of the volatile chloride.

Thermal decomposition:

$$Mo(CO)_6 \rightarrow Mo + 6CO$$
$$W(CO)_6 \rightarrow W + 6CO$$

Hydrogen reduction:

$$MoCl_5 + 2.5H_2 \rightarrow Mo + 5HCl$$
$$WCl_6 + 3H_2 \rightarrow W + 6HCl$$

Choice of process depends on the material to be coated, temperature which can be used, plating rate required, and properties desired in the deposit.

Metals are plated from these gases with high throwing power (Fig. 1). In plating tubes with molybdenum, which were made of woven or wrapped wire mesh, workers at Massachusetts Institute of Technology found that all the pores were filled. Wire mesh of copper, Nichrome, and molybdenum has been coated in this manner. With molybdenum wire mesh, it was necessary to preplate the molybdenum for satisfactory adhesion.

Properties of Plate Vary

Control of conditions for deposition determines the properties of the plate. The temperature of the part being coated is one of the most critical variables, followed closely by the pressure of the plating gas. Fine, crystalline deposits which tend to be hard and brittle are obtained at low temperatures. Higher temperatures give coarse, crystalline deposits which are soft and ductile. When temperatures are too high, powdery, nonadherent (frequently pyrophoric) deposits result due to premature reactions away from the surface. A uniform temperature on the part to be coated prevents deposit buildup at "hot spots".

Parts may be heated by internal resistance, high-frequency induction or external means. A moving induction coil is the best way to coat long specimens to prevent uneven or "flow" buildups. Wire-wound external heating with shunts is a convenient alternative in spite of lower efficiency because the chamber is coated as well as the specimen. The direction in which the heated zone moves is important. It should move toward the gas supply so that only exhausted gases pass over the deposited metal.

The best metallic deposits are obtained at pressures less than 20 mm. Hg, although good deposits have been reported at pressures up to and above atmospheric pressure. Often, high pressure and high concentration of plating gas give powdery, nonadherent deposits. Considering the low concentration of plating gas, it is advisable to use inert carrier gases, such as helium or argon, to assure adequate flow through the reaction chamber. In some instances, hydro-

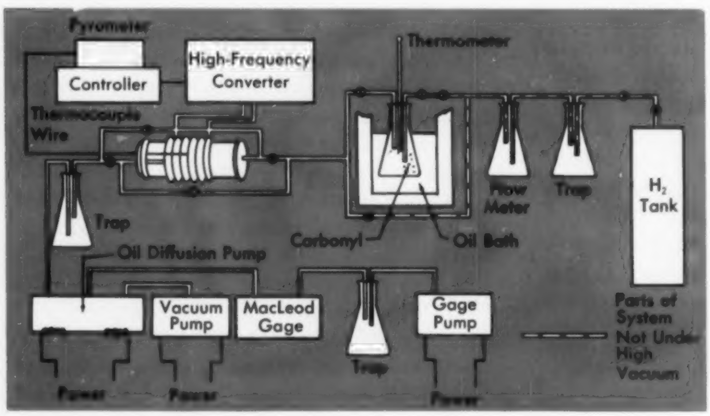


Fig. 2 – Equipment Designed by Sam Tour & Co. for Vapor Deposition of Molybdenum From the Carbonyl

gen alone may be an adequate carrier (as well as reactant gas in hydrogen reduction).

Adhesion Is Important Factor

Good adhesion or bonding of the deposit to the base metal is important, because this, to a large extent, determines the utility of coated parts. Three types of bonding may occur: diffusion, penetration, or mechanical. Temperatures must be high enough to cause diffusion of the coating into the base metal where this type of bond is needed. Slight irregularities in the surface actually promote "locking in" of the deposit because the metal follows the surface contours, as seen in Fig. 1.

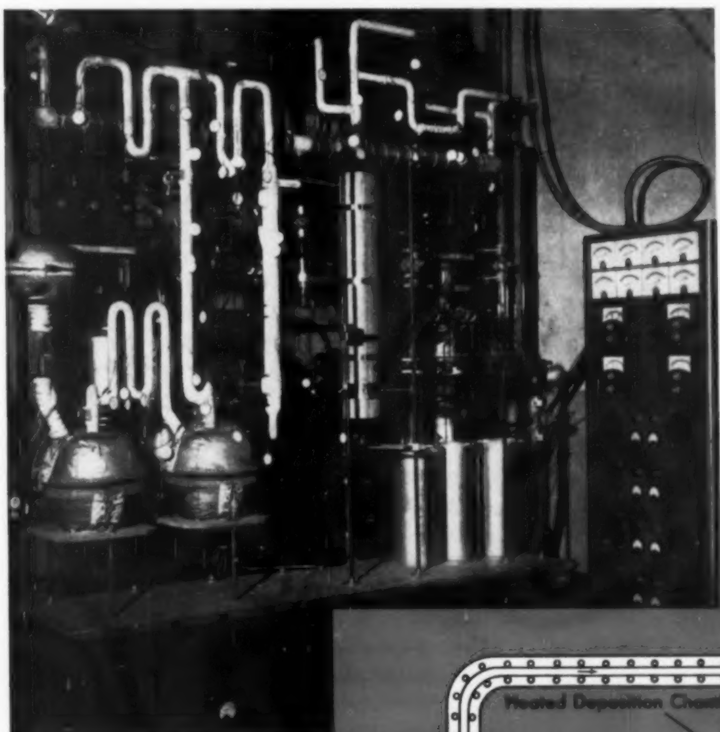
Pretreatment of Base Metal

Cleaning is important and preplating is frequently used to assure good adhesion of the deposit. Hydrogen, reacting with surface oxides, will form water vapor which cannot diffuse through the deposit – and blistering results. Sand-blasting, while adequate for some parts, may entrap fine particles in the surface and thus prevent adhesion during deposition.

When depositing on carbon steels and irons, flash coatings of at least 0.001 in. of copper, cobalt or nickel can be applied beforehand to prevent formation of brittle carbides and brittle iron-molybdenum intermetallic layers. These preplates will prevent blistering which otherwise might be caused by the release of gases from the base metal at the high temperatures and low pressures used. A vacuum pretreatment also may be used here.

Equipment and Economics

All equipment for vapor plating must be constructed to avoid leakage of air or contamination by carbon from seals or gaskets. Deposition systems may range from simple equipment, such as shown in Fig. 2, to the highly instrumented



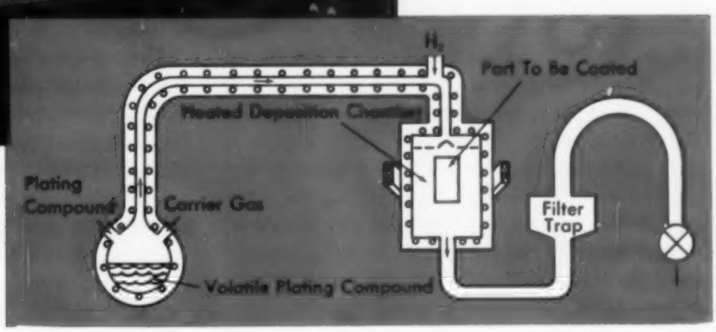


Fig. 3 – This All-Glass System, Highly Instrumented, Was Designed by Alloyd Research Corp. for Plating Molybdenum and Tungsten by Hydrogen Reduction of Chlorides. Drawing (inset) illustrates flow of gases

all-glass systems in Fig. 3. Figure 4 shows an all-metal system, constructed from everyday engineering materials. The relative costs of coatings can be compared on the basis of approximate cost of the raw materials required to give a coating 0.001 in. thick on 1 sq.ft. of surface, as follows:

CHEMICAL	COST
$MoCl_5$	$ 0.53
$Mo(CO)_6$	2.55
WCl_6	1.99
$W(CO)_6$	18.05

The costs, particularly of tungsten carbonyl, are expected to decrease as volume uses develop.

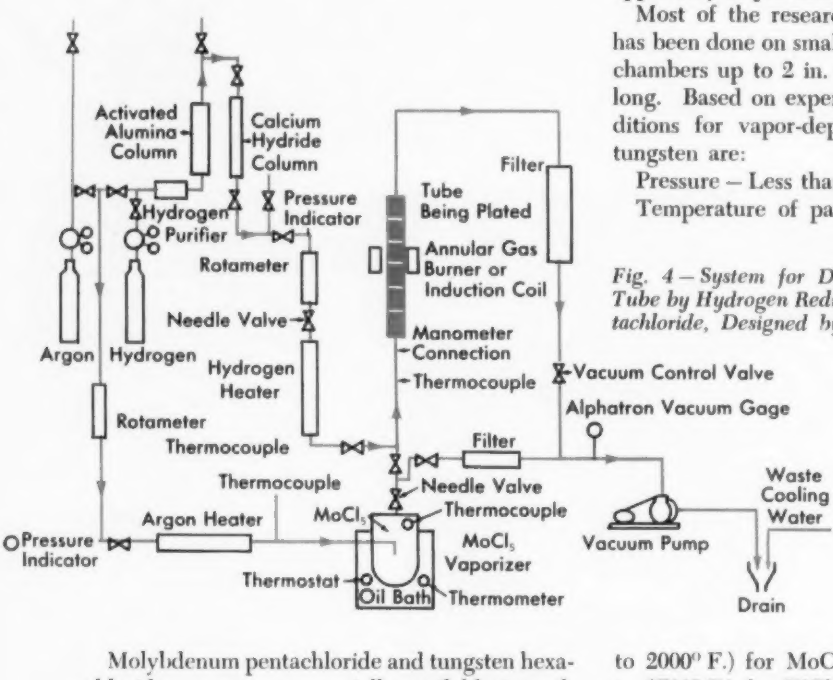


Fig. 4 – *System for Depositing Molybdenum on Tube by Hydrogen Reduction of Molybdenum Pentachloride, Designed by National Research Corp.*

Molybdenum pentachloride and tungsten hexachloride are now commercially available in such purity that a minimum of prepurification is required. The plating system illustrated by Fig. 4 is typical of what is used. The best molybdenum deposits have been obtained with a ratio of hydrogen to molybdenum pentachloride of at least 10 to 1, total pressure of 20 mm. Hg and temperatures ranging from 800 to 1100° C. (1475 to 2000° F.).

Adequate gas flow is assured by mixing the hydrogen-molybdenum pentachloride gases with an inert carrier gas. The carrier gas is either bubbled through the molten chloride or passed over its surface until saturated, then mixed with the proper volume of hydrogen. Maintaining the gas mixing system at temperatures around 350° C. (660° F.) prevents the chloride from condensing without hydrogen reduction. The melting and boiling points of the two chlorides are:

	$MoCl_5$	WCl_6
Melting point	194° C. (380° F.)	275° C. (530° F.)
Boiling point	268° C. (510° F.)	347° C. (660° F.)

Deposits ranging from a few hundredths of a mil to 0.25 in. or more thick can be made by hydrogen reduction of the chlorides. These deposits are dense and uniform and have well-defined columnar grain structures which are apparently impervious.

Most of the research on hydrogen reduction has been done on small equipment, with reaction chambers up to 2 in. diameter and up to 40 in. long. Based on experiments, the optimum conditions for vapor-depositing molybdenum and tungsten are:

Pressure – Less than 20 mm. Hg.

Temperature of part – 800 to 1100° C. (1475 to 2000° F.) for $MoCl_5$; 1000 to 1500° C. (1830 to 2730° F.) for WCl_6.

Temperature of vaporization of metal halide – 130 to 150° C. (265 to 300° F.) for $MoCl_5$; 165 to 230° C. (330 to 445° F.) for WCl_6.

Ratio of H_2 to halide gas – no less than 10:1.

The effect of temperature can be seen by a comparison of plating rates of molybdenum from the pentachloride at 5 mm. Hg. At 800° C. (1475° F.) plating rate is 0.005 in. per hr., while at 900° C. (1650° F.) it is 0.020 in. per hr.

Ceramic particles such as silica, uranium dioxide, silicon carbide, and alumina have been coated with molybdenum and tungsten. In coating these particles it is important to keep them fluidized so they may be plated uniformly. This

can be done either by gas flow or mechanical agitation. Metal-coated particles of this type can be useful for making high-temperature metal-ceramic bodies.

Carbonyl Decomposition or Pyrolysis

Molybdenum and tungsten hexacarbonyl are stable compounds which volatilize at low temperatures. At temperatures above 150° C. (300° F.), they decompose thermally, producing metal and carbon monoxide. In contrast to carbonyls of the first transition series, which are toxic and difficult to handle, molybdenum and tungsten hexacarbonyls are solids at room temperature and, according to Sax*, are relatively safe to handle.

Control of the process variables is perhaps more important in carbonyl decomposition than in hydrogen reduction. As in hydrogen reduction, control of temperature of the part and pressure of gas appears to be most critical. Low temperatures produce fine crystalline, generally hard deposits while high temperatures yield coarse crystalline deposits that tend to be soft and ductile. Due to the low decomposition temperature of carbonyls, premature decomposition may be caused by heat radiating from the specimen if its temperature is too high. This is a serious problem when long pieces are coated internally. Deposits obtained under such conditions are powdery and nonadherent.

Duplex Methods

Where diffusion produces good bonds between the base and the deposit, high specimen temperature should be used. The "duplex" method developed by Sam Tour & Co. for plating titanium can be used to offset the problems associated with high temperatures such as powdery deposits and changes in the microstructure of the base metal. Diffusion is assured by brief deposition at a high temperature. The temperature is then reduced to a point which permits useful deposits to be made and will not alter the microstructure of the material being coated.

Although it is reported that the metals can be deposited at atmospheric pressure in an inert atmosphere, the best deposits are obtained at pressures of 0.01 to 20 mm. Hg. Compared to the hydrogen reduction method at the same pressure, carbonyl decomposition is slower. But it can produce satisfactory deposits at lower temperatures. Plating rates of 0.0022 in. per hr. have been reported for molybdenum. Tungsten may be plated faster because it is less susceptible to carbon contamination at high pressures.

*Dangerous Properties of Industrial Materials, by N. Irving Sax, Reinhold, New York, 1957.

Wear Resistant Coatings

The carbonyl process permits the deposition of carbide surfaces or carbon-containing deposits having excellent wear resistance. Carbon content can be controlled from 0 to 35 at.% – hence hardness or wear resistance can be controlled. When the plating gas is made up of carbonyl alone, deposits contain large amounts of metal carbide. Mixing hydrogen with the plating gas decreases the carbide content but increases the carbon content (it also serves as a carrier gas). By adding water vapor to the carbonyl and hydrogen, however, carbon formation can be decreased, as shown for molybdenum coatings:

Plating Temperature	H_2O in Plating Gas	Vickers Hardness
500° C. (930° F.)	0%	1030
	2	1000
	8	800
550° C. (1020° F.)	0	920
	2	740
	8	430

Parts in the above tests were prepared under identical conditions – H_2 pressure equaled 0.12 mm. Hg and CO 0.08 mm. Hg. Annealing these parts reduces the hardness of the coatings in some instances to as low as Vickers 200.

Control of the partial pressures of gases in the plating gas mixture is important for a useful deposit. The following partial pressures are reported to give the best metallic deposits: $Mo(CO)_6$, 0.02 mm; $W(CO)_6$, 0.10 mm.; water vapor, 0.20 mm.; hydrogen, 2.0 mm. Temperatures used should be in the range 350 to 600° C. (660 to 1110° F.).

Tungsten deposits are generally harder and may be more difficult to produce because the carbonyl is more easily reduced. But tungsten is less likely to form carbides or powdery deposits at higher temperatures and pressures. A "pack" technique has been developed by National Research Corp. The piece to be coated is packed in a mass of finely divided metal carbonyl powder and is heated by resistance. Recommended temperatures for optimum plating are: Mo, 160°C. (320°F.); W, 170°C. (340°F.). Deposits up to 0.00004 in. are obtained. By introducing hydrocarbons, hydrogen sulphide, or boron-containing gases into the plating gas mixture, a variety of modified surfaces are obtained. These contain metal carbide, sulphide, or boride.

Fig. 5 – Threaded Copper Tube Which Has Been Vapor Plated With Molybdenum. Large surface discontinuities tend to produce a fine-grained equiaxed structure. 75 ×

Properties of Deposited Metals

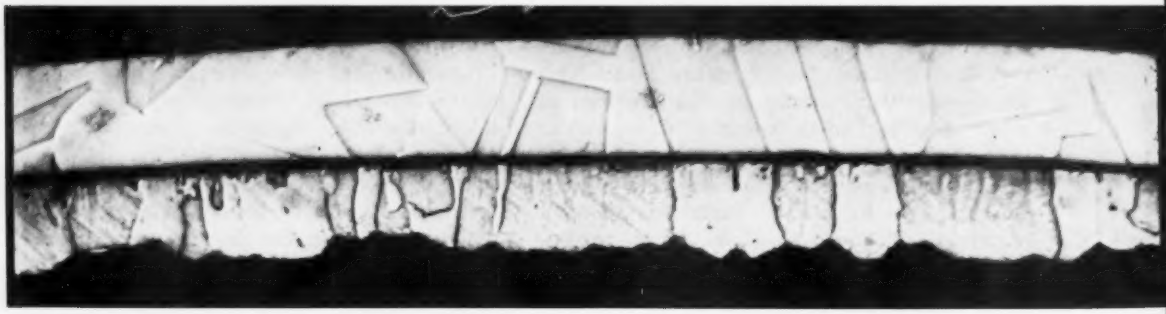
Thermal and electrical properties of vapor-deposited molybdenum and tungsten are affected by the density of the deposit. Inclusion of carbon or carbides may alter these properties significantly. Vacuum-tight seamless tubes of tungsten, 0.04 in. thick, have been deposited from tungsten hexachloride at 2000° C. (3630° F.) on a molybdenum tube ¼ in. diameter by 14 in. long. Similar vacuum-tight deposits of tungsten have also been made on copper at lower temperatures.

Hardness of deposited coatings ranges from Vickers 50, for single-crystal tungsten prepared by chloride reduction, to Vickers 2000 for hard tungsten coatings containing carbon. Molybdenum deposits with Vickers hardness of 170 to 1560 have been obtained by hydrogen reduction of the pentachloride; here, hardness values of 230 to 350 are most common. Alloyd Research Corp., by using highly purified raw materials, expects to produce ultrapure deposits of molybdenum and tungsten which are considerably softer than those produced up to now.

The columnar grain structure of molybdenum deposited from the chloride is well defined. Although its lateral strength is relatively poor, this may be overcome by working. Large surface discontinuities, such as threading (Fig. 5), tend to produce more equiaxed and fine-grained deposits. Molybdenum and tungsten coatings deposited from carbonyls are harder and more brittle than those produced by hydrogen reduction. This may be due to carbon entrapment during decomposition. Annealing the coating will soften it, but this may weaken its bond to some metals.

Excellent bonds have been obtained in a number of applications. For example, a ½-in. long, hardened steel specimen was coated with a 5-mil thick molybdenum layer. After subjection to a 20% compression, parallel to the surface, the deposit showed no signs of cracking or spalling. Even with additional compression, at least part of the failure occurred in the plate, and no spalling was observed. Average shear strength was 100,000 psi. parallel to the bond, but only 25,000 psi. normal to the bond. This is attributed to the columnar crystals.

Fig. 6 – Grains of Molybdenum Vapor Plated on Copper Have the Same Crystal Lattice Orientation as the Basis Metal. 125 ×. (Courtesy Climax Molybdenum Co.)



Mechanical Testing With a 3000° F. Radiant Heat Furnace

*By J. K. HOY**

A radiant heat furnace which operates up to 3000° F. is powered by quartz pencil lamps. Predetermined test temperatures with programed heating cycles are readily obtained and accurately stabilized with an automatic control recording system. The test chamber is simple to operate and can be adapted to many uses. (X24f, Q27, 2-62)

Jets and missiles flying at speeds of mach 4 and upward generate skin temperatures and conditions that challenge the best of the heat resistant materials. Consequently, before such materials are used in engines or airframes, they must be tested thoroughly. Testing in actual flight, of course, is virtually out of the question. However, designers must have unchallengeable data to select the proper materials. We must, therefore, do our best to simulate time, temperature and stress conditions in the laboratory.

The radiant heat system discussed here was designed for this purpose. Such items as specimen shape, heating requirements, ease of loading, and strain measuring equipment all had to be considered. We wanted the temperature range to be as broad as possible; furthermore, 3000° F. must be reached and stabilized within 3 min. or less. In addition, the test chamber should use any atmosphere: air, vacuum, partial pressure, pressure or inert. This chamber also had to be large enough to hold stress-strain apparatus, provide easy access for loading and unloading, and be capable of performing various heating and cooling cycles. Furthermore, temperatures across the gage section of a tensile test had to be as uniform as possible.

Deficiencies of Conventional Equipment

Conventional heating methods and equipment do not meet these requirements. Furnaces with the standard Nichrome or Kanthal elements cannot reach this temperature range, nor will they heat as rapidly as desired. Molybdenum, tantalum or tungsten furnaces, though capable of rapid heating and high temperatures, are restricted to vacuum, inert or reducing atmospheres. Graphite elements can reach still higher temperatures but they produce carbon monoxide when operated in air; this may or may not be desirable. Also, the large masses of graphite needed will act to reduce heating and cooling rates.

High-frequency heating introduces molecular and atomic motions within the test material; their effect may complicate results. If the test specimen is heated by its own resistance, the problem of uniform temperatures across the gage length is introduced when neck-down begins before failure. Platinum resistance furnaces can heat to 2700° F., but are expensive and do not provide the rapid heating rates that are needed.

Heating Elements Are Quartz Lamps

The essential item in our furnace is the G.E. T-3 quartz pencil lamps. As Fig. 1 shows, these lamps are partially imbedded in semicircular grooves machined in the reflector housing. This housing (of gold-plated copper) and the electrical

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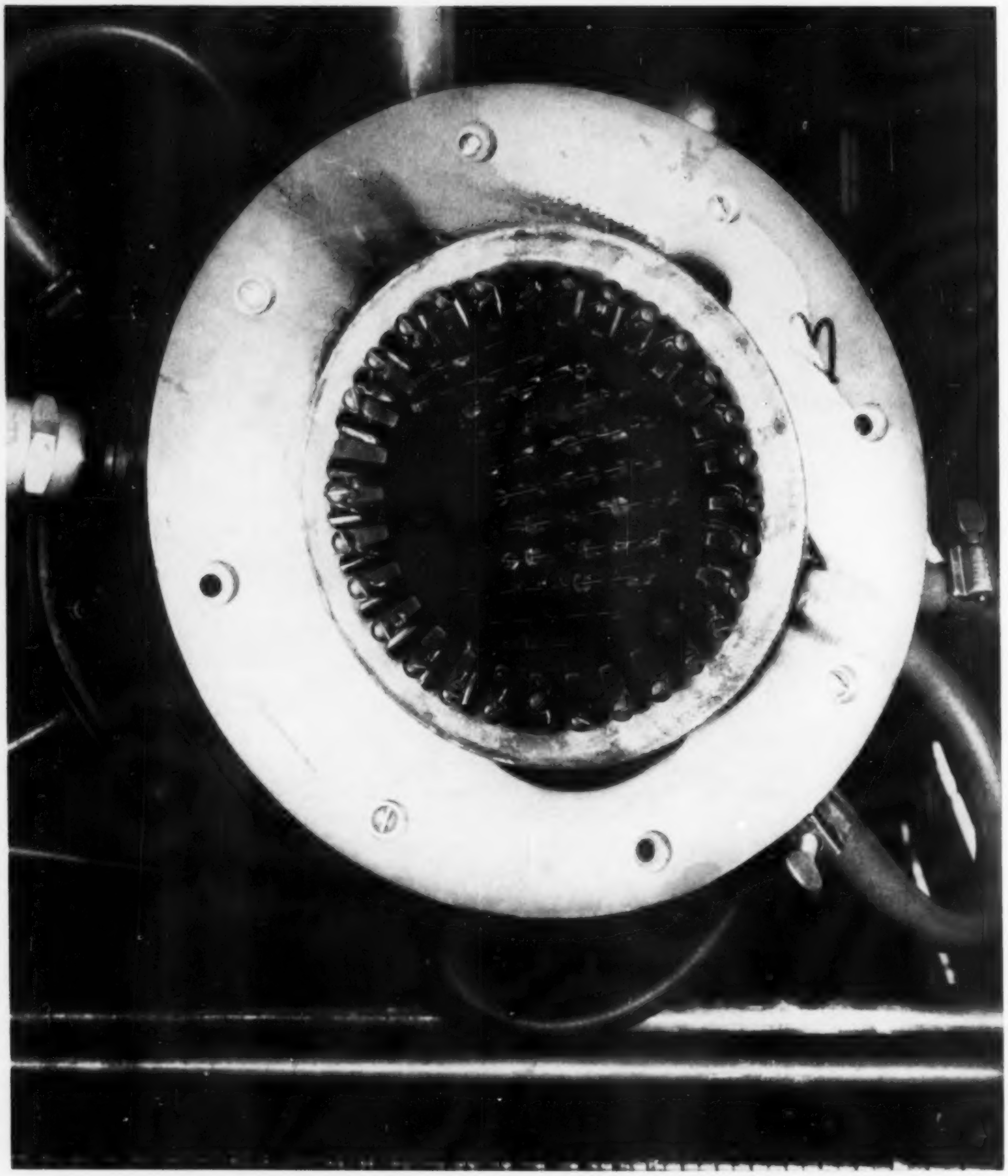

Fig. 1 – *Chamber of Furnace Showing T-3 Quartz Pencil Lamps. The housing (of gold-plated copper) and the electrical seals at the lamp ends are cooled by purified water*

seals at the lamp ends are cooled by purified tap water which circulates through the housing walls and the power connectors.

All metal parts are machined from electrolytic copper and joined by silver brazing. An epoxy resin, which is heat resistant, provides electrical insulation. Environmental adaptors and housings for the stress-strain accessories are made from weldable aluminum alloy.

The internal bore of the furnace is 4½ in. in diameter by 10 in. long, and holds 30 (500-w., 115-v. a-c.) T-3 quartz pencil lamps. Internal grooves of the reflector housing are plated with gold to prevent corrosion and provide good

reflectivity. A schematic sketch, shown in Fig. 2, describes the components of the furnace and accessories.

Power and Control Requirements

Although each lamp is rated at 500 w., it can be operated up to about twice the rated voltage; maximum power for the furnace is about 37,500 w. Replacement with double wattage filament, 1200-w. lamps permits the furnace to operate as high as 108,000 w. Temperature is controlled and recorded by an ignitron controller in conjunction with a Speedomax recorder.

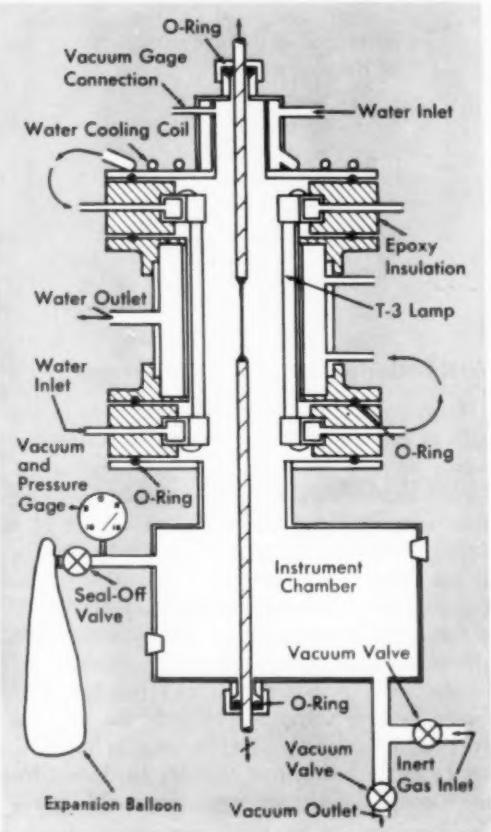

Fig. 2 – Schematic of Radiant Heat Furnace. The balloon is a safety feature. As the furnace heats, the atmosphere in it expands. The balloon then expands to accommodate the larger volume

When operated as rated, the lamps will last more than 5000 hr. However, to obtain 3000° F. in the specimen, power output must be slightly more than the rated capacity. Fortunately, this has not harmed lamp elements even after continuous operation for several hours. For faster heating and temperatures above 3000° F., the lamps can be operated up to maximum power for a minute or more without apparent bad effects.

We obtained very good results from a temperature survey on a typical tensile specimen. With seven Chromel-Alumel thermocouples attached at half-inch intervals along the gage, and temperature control maintained on the thermocouple at the center of the gage, a maximum temperature difference of 20° F. was measured at either end after a 1-min. soak. Though this was excellent, we expect temperature distribution along the gage to be much more level with longer lamps.

These lamps have other advantages. For example, low mass inertia of the tungsten element permits instantaneous radiant heat. The lamp elements can be operated up to 5800° F., and the T-3 lamps will work in almost any atmosphere, and are readily available in various sizes and power capabilities.

Some Design Problems

Though these lamps appeared to answer most of our questions, certain undesirable features had to be designed out of the furnace. The end seals (where electrical leads protrude from the inside of the lamp envelope) could not be operated above 650° F. in air. Also the softening temperature of the quartz envelope is about 3000° F.; its melting point is 3193° F. Both problems were solved by providing water cooling in these zones. However, if this furnace is used in areas with relatively impure water, the water must be purified before it is used for cooling.

A hazardous feature of the furnace is the high voltage required for its operation. Personnel must be thoroughly familiar with the furnace and its controlling and recording equipment to minimize the potential danger.

Wide Use Is Possible

This furnace can be readily adapted to oxidation and recrystallization studies under various simulated conditions of altitude and temperature. We can also evaluate the effects of transient heat on insulation and thermal stresses on various components. Many other projects are possible. In fact, with the wide range of temperatures and atmospheres that can be obtained, this furnace should become more and more useful as a research tool.

Forming Cones by Metal Gathering

*By H. P. TARDIF**

Cones can be formed without danger of rupture by recessing the flat workpiece in the die cavity rather than over it. Side effects cause the metal near the base of the cone to be thicker than the original blank. (G4b; NM-k34)

THE DEFORMATION MECHANISM of explosive or high-energy-rate forming is not yet understood. In making dome-shaped parts, it can be described as one of rapid deep drawing because walls of the domes are thinner than the original blank – a characteristic of deep drawing. A different response occurs when the workpiece is recessed in the die cavity, as in Fig. 1, rather than being placed over the die as is the conventional procedure. The walls of the part will contain regions which are thicker than the original blank. We call this particular response metal gathering.

Explosive forming of copper blanks in the modified setup produced shapes shown in Fig. 2. The blank was 3 5/16 in. in diameter and ⅛ in. thick. Only the weight of the explosive charge and the length of the confinement tube were changed to produce the various forms.

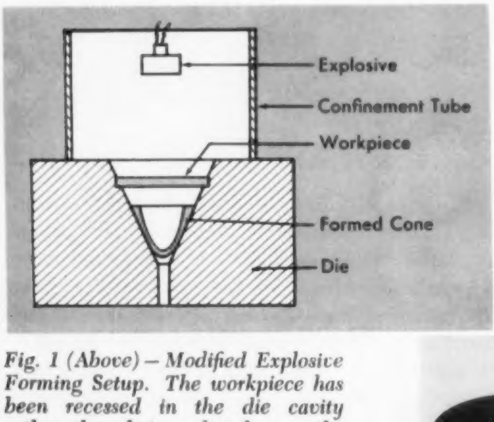

Fig. 1 (Above) – Modified Explosive Forming Setup. The workpiece has been recessed in the die cavity rather than being placed over the die as is the conventional procedure

Metal Gathering Increases Wall Thickness

Hardness and thickness measurements in the walls of these shapes show that blanks respond in two ways to the forming pressure. For example, hardness and thickness measurements taken across the longitudinal cross section of a copper cone are plotted in Fig. 3. In part of the cone, the wall thickness exceeds that of the original blank – metal gathering has taken place. At the apex, deep drawing has made the wall thinner than the workpiece. The hardness of the zone of "zero deformation" (no apparent change in wall thickness) exceeds the original hardness of the blank. The increase in hardness may be attributed in part to work hardening by the passage of the stress wave. It is also prob-

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Fig. 2 – Shapes Made in the Modified Setup by Varying the Explosive Weight and the Length of the Confinement Tube. The original workpiece at left is 3 5/16 in. diam. and ⅛ in. thick

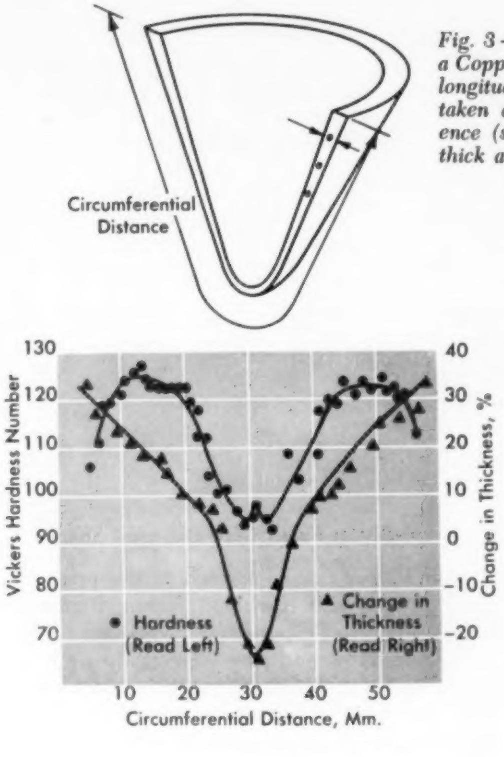


Fig. 3 – Hardness and Thickness of the Walls of a Copper Cone. The cone was cut in half through longitudinal section and measurements were taken at specific distances along its circumference (see inset). The original blank was ⅛ in. thick and had a Vickers hardness number of 50

able that in this region of "zero deformation" both metal gathering and deep drawing have occurred. The net effect: no apparent change in thickness but an increase in hardness. We have also found that, for the same amount of deformation, the change in hardness in the metal gathering zone is much higher than in the area of deep drawn metal.

Metal gathering may be significant in forming cones and dome-shaped parts. For example, some present applications require welding the workpiece in a conical shape before explosive forming. A flat workpiece either ruptures or does not fill the die cavity. Metal gathering would permit fabrication of cones directly from flat blanks. A more uniform product would result, and quality of the weld would not determine either formability or service reliability.

Making Compacts by Explosive Forming

*By E. W. LaROCCA**

The method finds a new use in a compacting press. Acting through pistons, the explosive force compresses powders and solid materials. (G1, H14; NM-k34)

Much of the interest in explosive forming centers around its potential use in fabricating hard-to-work sheet metal alloys. We have investigated a technique for utilizing explosives in a double-piston press to compress powder or solid samples. A simplified diagram of the press is shown in Fig. 1. Its design includes provision for cylinders of explosives, each 1 in. diameter and 1 in. high. Simultaneous explosion of charges drives the pistons by means of the buffer plates and compresses the sample. Parts will not be contaminated by the explosive because the force is transmitted to the workpiece or powder by the buffer plates and pistons.

We prepared compacts from sponge cobalt, coarse titanium filings, and solid graphite disks. The cobalt sample was compressed to a homogeneous disk 0.012 in. thick. After forming, the density of the titanium compact was only 5% less than that of the original bar from which the filings were obtained. The graphite workpiece was a solid disk, 1/16 in. thick, machined from a ½-in. diameter bar. Compression increased its diameter and density without cracking it.

*Physics Div., Research Dept., U. S. Naval Ordnance Test Station, China Lake, Calif.; now on leave at the U. S. Naval Postgraduate School, Monterey, Calif.

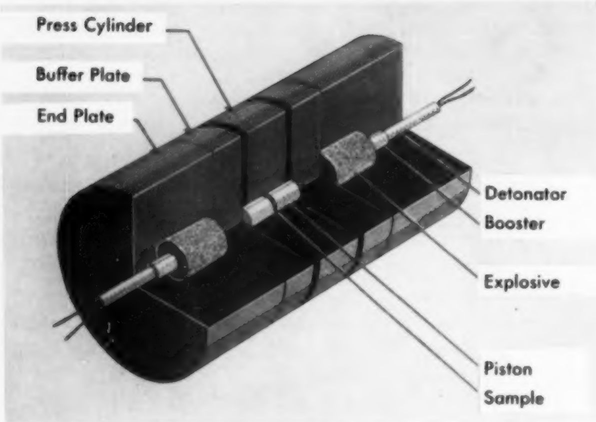


Fig. 1 – Cutaway Drawing of the Compacting Press. Forces from the simultaneous explosion of the charges are directed to the sample through the buffer plates and pistons

Ductile Binders Required

Further tests have shown that the powdered starting material should contain at least one ductile ingredient to prevent brittleness of the formed disk. For example, a compact of diamond powder and coarsely ground silicon appears to be a coherent solid, but the disk crumbles when removed from the press. On the other hand, a mixture of black oxide with powdered aluminum added as a ductile binder formed a strong, solid disk. Titanium carbide, usually hard and brittle, can be formed into a coherent disk if nickel is present.

Machined Piston Faces Give Different Shapes

Other shapes can be formed in the press by using pistons with machined faces. Figure 2 shows examples of pistons and the resulting compacts. The cross and ring were made from titanium and iron filings; the disks were formed from powdered calcite and cobalt. Various shapes have been produced from other materials, but we sometimes experienced difficulty releasing the compacts from the pistons. Dry lubricants, such as a molybdenum sulphide-graphite mixture, prevent sticking when applied to the faces but purity of compact is sacrificed.

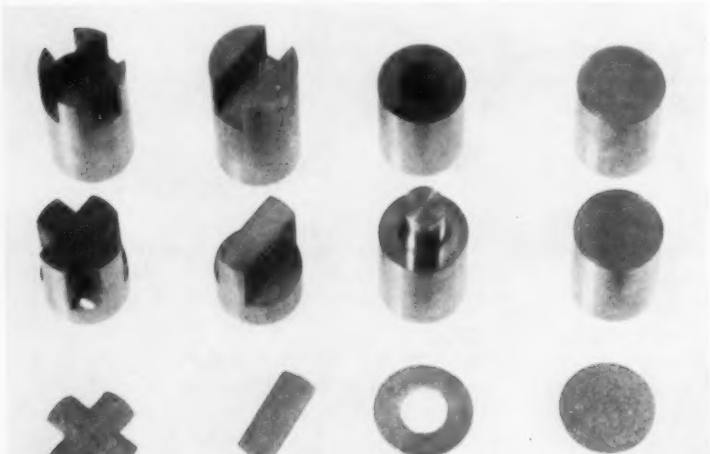


Fig. 2 – Piston Faces Can Be Machined to Give Shaped Parts. Compacts below are made of titanium and iron filings, powdered calcite and cobalt

A New Tool for Case Carbon Evaluation

*By ALAN GOLDBLATT**

A direct-reading, vacuum spectrograph can be used to determine the carbon gradient in steel. This method is compared with analyses of carbon by combustion. (S11k, 1-53; ST, *C*)

DIRECT-READING SPECTROGRAPHS (Quantometers) have been used industrially since 1946. Their utility for complete ferrous analysis has been hindered because two significant elements in iron and steel – carbon and sulphur – cannot be routinely analyzed. These elements cannot be determined because their principal and most sensitive lines are located in the region of the spectrum where air absorbs most of the emitted radiation.

These problems have been overcome with a vacuum direct-reading spectrograph, the Quantovac, developed by Applied Research Laboratories. The instrument operates under vacuum, to minimize air absorption. Prior to making an analysis, the sample chamber (Fig. 1) is flushed with argon for 20 sec. This simplifies the loading problem and excludes the need for a vacuum seal in the sample chamber. The Quantovac has been used to analyze carbon steels, low and high-alloy steels, and cast irons. It can analyze 23 elements simultaneously with a complete analysis every 2 min. Precision is comparable or better than routine analysis by other methods (see Table I).

In cooperation with Diamond Chain Co., Inc., Indianapolis, Ind., carburized specimens were analyzed to see if this method was sufficiently accurate for measuring case depth.

Carburized specimens were analyzed by the

*Consultant, Applied Research Laboratories, Inc., Glendale, Calif. Thanks are extended to George J. Shubat, chief metallurgist, Diamond Chain Co., and his staff for supplying the case hardened specimens, for performing the combustion carbon determinations, and for correlating the data. Acknowledgment is made to John Odom, Applied Research Laboratories, Inc., for the Quantovac analyses.

Table I – Precision Data on Quantovac Determinations

	Sample 1161			Sample 1162		
	Conc.*	S.D.†	C.V.‡	Conc.*	S.D.†	C.V.‡
Carbon	0.15	0.0017	1.2	0.40	0.0039	0.97
Phosphorus	0.053	0.0006	1.1	0.045	0.0011	2.4
Sulphur	0.019	0.0005	2.6	0.019	0.0005	2.6
Manganese	0.36	0.0034	0.94	0.94	0.0047	0.50
Silicon	0.047	0.0015	3.1	0.28	0.0021	0.75
Copper	0.34	0.0056	1.6	0.20	0.0027	1.3
Chromium	0.13	0.0012	0.92	0.74	0.002	0.27
Molybdenum	0.30	0.0016	0.53	0.08	0.0017	2.1
Nickel	1.73	0.009	0.52	0.70	0.0028	0.40

*Concentration of element in per cent.

†Standard deviation expressed in concentration.

‡Coefficient of variation, standard deviation in per cent of amount present.

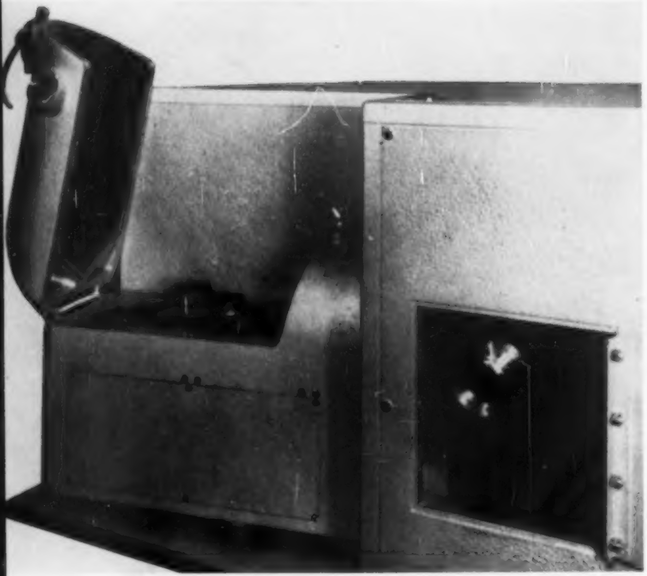


Fig. 1 – The Sample Chamber of the Vacuum Spectrograph Is Flushed With Argon for 20 Sec. Before Making an Analysis. The spectrograph operates under vacuum to minimize air absorption

Quantovac using a point-to-plane technique. The counter electrode was a commercially available fine silver rod, ¼ in. diameter, which is pointed to a 120° included angle by means of a lathe. The spectrographic discharge samples an area which is about ¼ in. diameter and penetrates into the specimen surface some 0.001 in.

This permits local sampling and also allows a number of determinations to be made at various levels during a case depth study, if the surface area permits. The combustion method for determining carbon, in comparison, requires 0.5 to 1 g. of metal for each analysis and is therefore an average analysis at each level.

Three specimens 9/16 in. diameter by 2½ in. long of A.I.S.I. 4322 steel were carburized to a depth of 0.030 to 0.040 in. and oil quenched. These specimens were analyzed by the following procedure: A piece ¾ in. long was cut from each sample with a carborundum cut-off wheel, then clamped individually in a V-block and skimmed with a Reed precision surface grinder, until the sample would not rock on the surface plate. This surface was identified as the zero level. Carbon analyses were made with the Quantovac at 0.002-in. levels throughout three pins. These specimens were also analyzed by the combustion method, using a Leco carbon determinator.

Results of Analyses

A comparison of results is given in Fig. 2. The combustion determinations are superimposed on the Quantovac results. At each position, the combustion result appears as a single point, since it was necessary to combine turnings from the three test specimens to obtain sufficient metal for an accurate analysis. The data are in close agreement for both methods of analysis. They would be even closer if an allowance were made for the preliminary grind to flatten the pin prior to the Quantovac determinations.

The vacuum direct-reading spectrograph offers a sensitive and accurate method for determining carbon content of case hardened parts. It has many other potential applications in controlling heat treating processes, and in research and development.

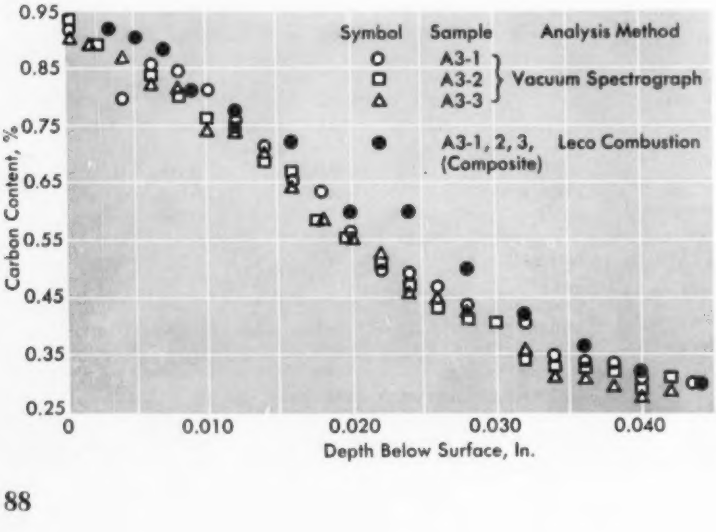


Fig. 2 – Vacuum Spectrograph Method Compared With Conventional Combustion Analysis of Carburized A.I.S.I. 4322. Cylindrical specimens were 9/16 in. diameter by 2½ in. long

New Techniques Broaden Forging Picture—II

*By J. H. JACKSON and H. B. GOODWIN**

Cored forgings, a unique multiple-ram forging technique, high-energy forming and improvements in conventional methods are helping to make better forgings at lower cost. Further advances are expected from fundamental studies of the forging process though research is still in the early stages. (F22)

LAST MONTH, the second in this series of articles discussed five new forging developments: the counterblow hammer, the "impacter", the "precision forging" process, the "continuous grain flow" process and roll forging. This article will give details of developments in cored forgings, multiple-ram techniques, and high-energy forming. Improvements in conventional equipment and progress in research will also be discussed.

Cored Forging

Originated in England for making brass plumbing fixtures (elbows, tees, crosses, and the like), this process has also been used to form a wide variety of parts from copper, aluminum, bronze, aluminum alloys, unalloyed titanium, and other materials.

Formerly, hollow or tubular components were machined from conventionally forged blanks. Since it is obviously more satisfactory to forge the hollow into the part, the cored forging process was developed. Briefly described, coring punches, one or more, are forced into the heated billet while it is held in closed and locked dies. The displaced metal flows out against the die surfaces, conforming to their shape, and the interior hollows are formed by the punches. Figure 1 illustrates a typical part.

The main difference between cored and solid forging is in the way pressure is applied. In solid forging, pressure is exerted by closing the die halves, whereas in cored forging it is exerted by the coring punches. Cored forging is commonly carried out in mechanical presses, and split dies are frequently employed.

Complex parts are made by using several coring punches which may operate in different planes. Up to four cores in a single plane may be produced. Cores need not be round in cross section but may have any shape, and a short section at the end of any core may have a different (but smaller) shape than the rest of the core. Since coring punches must not be allowed to meet during forging, hollows are always blind ended. For such parts as plumbing fittings, punches can come close enough so that very little metal needs to be drilled out.

There are some design limitations. Core size must be proportionate to the piece – in other words, large enough so that the displaced metal will fill the die opening. Minimum wall thickness is about 0.10 in. Advantages are:

1. Very close tolerance – accuracy to 0.005 in. is possible.
2. Substantial saving of metal – subsequent machining is minimized.
3. No draft required – forging may have parallel walls.
4. Complex shapes easily handled.
5. Excellent properties in the metal – this type of working produces ideal grain flow.
6. Elimination of porosity.
7. High production, low cost.
8. Excellent die life (for brass, up to 100,000 pressings with repolishing after every 15,000 pressings).

*Mr. Jackson is manager and Mr. Goodwin is consultant, metallurgy department, Battelle Memorial Institute, Columbus, Ohio. This is the last of three articles on the forging industry today. Industrial trends were discussed in the first article (July 1959), while last month's and this one cover some of the newer forging developments.

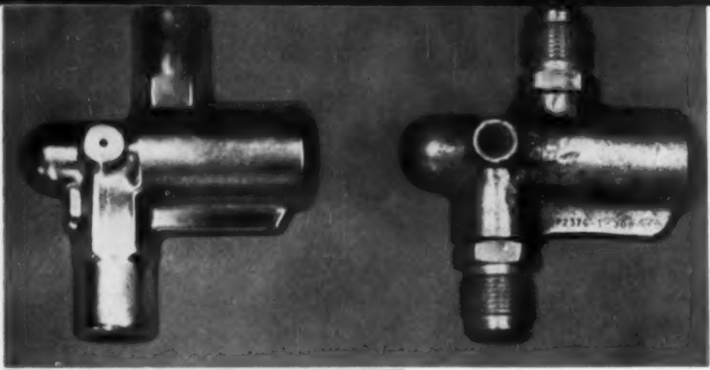
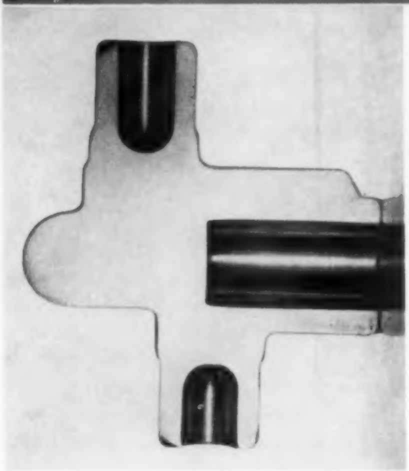


Fig. 1 – The One-Piece Cored Forging Has Replaced the Four-Piece Cast Assembly on the Right. Lower view shows location of cores; parts were produced from a round brass rod by one blow of a 200-ton press. (Courtesy Bridgeport Brass Co.)



Multiple-Ram Technique

A unique method for making intricate forgings of heavy steel has been developed by Cameron Iron Works, Houston, Tex. Announced in the early 1950's, this process was developed mainly for making heavy oil well fittings, but it is adaptable to a wide range of parts. Bosses, flanges and cavities, and shapes which include a number of angled holes and orifices, are easily formed so that little machining is required.

Key to the process is a huge multiple-ram hydraulic press. It incorporates an 11,000-ton main vertical ram, two opposed 6000-ton horizontal side rams, and a 3000-ton auxiliary ram for piercing and similar operations. For most forging, the side rams hold split dies together while the vertical ram forces metal into the die cavities in a confined upsetting operation. After a blocking operation by the main ram, the auxiliary piercing ram may force a relatively small punch into the hot metal. This displaces the metal under high pressure to all corners of the die cavity. When this auxiliary piercing ram is used in this way, the process is identical in principle to the cored forging process discussed in the previous section. The auxiliary ram and sometimes the side rams are also used for backward extrusion of metal around the rams to form certain parts. A special manipulator transfers the heated billet from the heating furnaces to the press.

Figure 2 shows a multiple-ram forge producing an interceptor valve for a steam turbine. The inset shows horizontal and vertical forging combined in one operation. Advantages are:

1. Intricate shapes, including hollow parts, can be made.
2. Little machining is needed.
3. Favorable grain flow produces excellent properties.
4. Operation is economical.

High-Energy Forming

In the past two or three years, explosive forming and other processes which use high deformation rates have attracted attention. So far, most studies have involved cold forming methods for sheets and plates, though a little work has been done on high-velocity hot forming. So many claims and counterclaims have been made for explosive forming that it is difficult as yet to assess the merits of the process. As an example, many investigators claim that metals flow like liquids at extremely high deformation rates. Consequently, less total energy and lower loads are needed for a given amount of deformation. It has been said that metals take the desired shape "before they have time to resist".

Explosive forming is being developed quite extensively by the aircraft builders because it offers much promise in forming large parts from high-strength sheet. Energy is supplied by explosives, or gas at high pressure. One of the attractive features is low equipment cost. Some methods need nothing more than a tank big enough to hold the die and blank. Only a female die is required; the blast forces the metal into it.

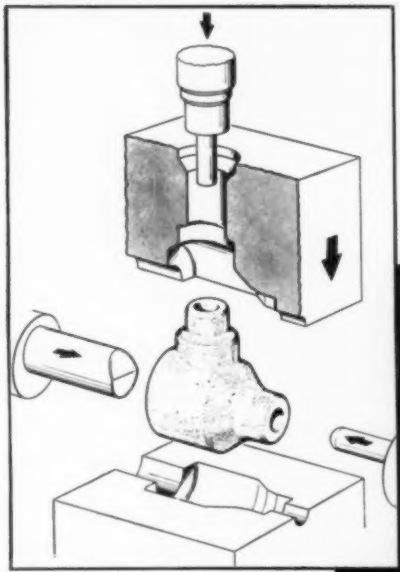
There is probably an optimum deformation rate for each operation and for each metal which will have to be established through research. One problem that is causing some trouble is the maintenance of thickness tolerances.

Metals that have been formed successfully include carbon, alloy and stainless steels, aluminum alloys (both annealed and hardened) and titanium. "Spring back" is virtually eliminated in materials that are explosive-formed; this is an added advantage.

A novel system of high-velocity forming, known as the "Dynapak" process (see Fig. 3), was exhibited at the 1958 National Metal Congress in Cleveland by the Hyge-Convair Div. of General Dynamics Corp.

The machine operates through differential gas pressure on two sides of a piston in a closed cylinder. The forging ram, equipped with conventional dies, is attached to the piston. At the instant before the piston starts its stroke, low-pressure gas acting on a wide area on one side of the piston balances gas at much higher pressure but acting on a smaller area on the other side of the piston. On the high-pressure side, the piston rests against an orifice plate equipped with an O-ring seal; this prevents the high-pressure gas from exerting pressure on the entire piston area.

Gas pressure increases slowly on the high-pressure side. Finally, the equilibrium is upset. The piston moves away from the orifice plate, and the seal opens. *Instantly* the entire bottom area of the piston is exposed to the high-pressure gas. Since the pressure on the high-pressure side is many times that on the low-pressure side, the piston moves exceedingly rapidly – about 400 ft. per sec. Travel rate can be controlled by tapered metering pins which are attached to the high-pressure side of the piston and project through the orifice. Machines with 12-in. and 24-in. strokes and energy outputs ranging up to 360,000 ft-lb. per stroke are offered.



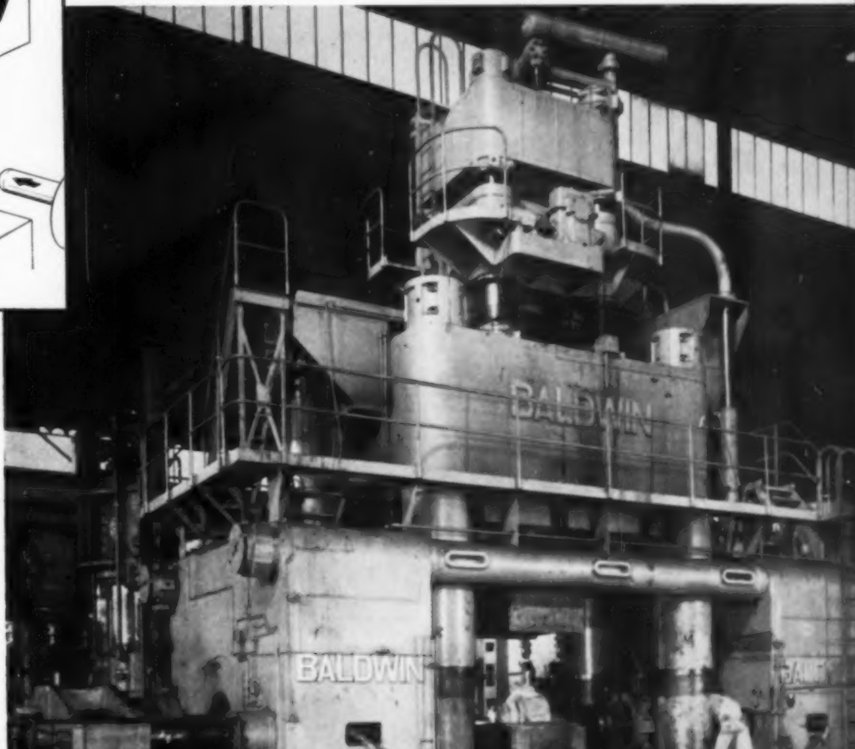


Fig. 2 – A Multiple-Ram Forge Produces an Interceptor Valve for a Westinghouse Steam Turbine. Inset shows movement of rams. (Courtesy Cameron Iron Works)

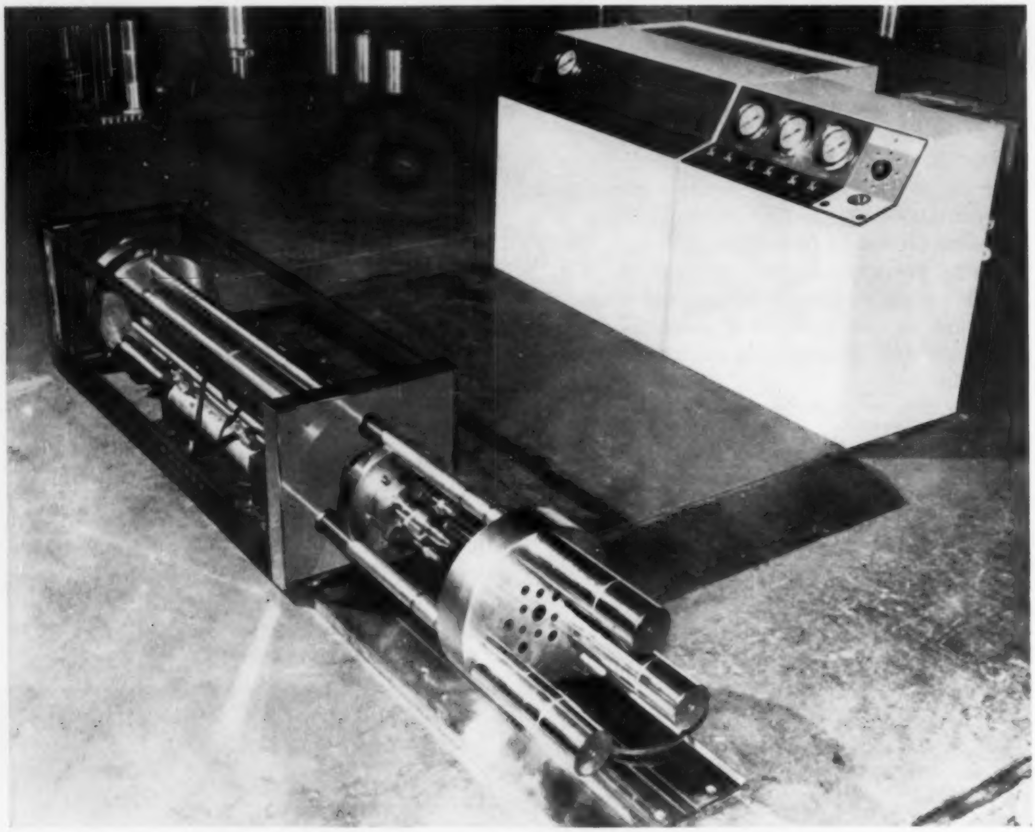


Fig. 3 – High-Energy-Rate Tool for Forging Small Parts. (Courtesy Hyge-Convair Div., General Dynamics Corp.)

Other Forging Developments

While these new forging techniques were being devised, there was also progress in traditional forging methods. Not only have hammers and presses increased in efficiency, but methods for making dies have become almost automatic.

At first glance, a modern steam drop hammer looks little different than the hammers of 100 years ago. This is also true of mechanical and hydraulic presses. All of them, however, are many times more productive than earlier models. One cause for this has been the trend to ever larger equipment. However, efficiency has also increased. Modern hammers and presses are vastly more productive than early models of the same nominal rating. For example, the 2000-lb. (usual nominal rating based on weight of falling parts) steam drop hammer of 1846 struck a 4500-ft-lb. blow; with an anvil ratio of 5 to 1, forging efficiency was 5%, and the hammer produced 100 lb. per hr. of low-carbon steel forgings.

In contrast, a modern hammer of the same 2000-lb. nominal rating strikes a 27,000-ft-lb. blow at a forging efficiency of 80%. It produces 650 lb. of low-carbon steel forgings every hour. The anvil ratio is 20:1, and the percentage availability is 90% (as opposed to 50% for the 1846 model). With the larger equipment being used, average tonnage production per man-hour today is 25 to 30 times what it was 40 years ago.

There have been three major improvements in the steam drop hammer since its conception by England's Nasmyth in 1838. First came impression dies, accurately machined to shape; these were devised by American firearm manufacturers at about the time of the Civil War. Until then, most forging had been done with flat dies, or occasionally with very crude impression dies. The second major advance was the advent of the double-acting steam hammer in Midvale, Pa., in 1888. In this, steam was used not only to lift the ram, but to exert additional force on

the downward stroke. As the third major improvement, a much better arrangement for steam valves was invented in 1933.

Starting in the early 1920's, the high-speed forging press was gradually developed to be useful for closed die forging. Older presses, designed for other purposes, were too slow and not rigid enough for this. Modern presses have been important in increasing forging productivity. A 2000-ton mechanical forging press will duplicate forgings produced on 4000-lb. steam and 5000-lb. board hammers.

In 1958, a fully automatic 2500-ton mechanical press, built by the Erie Foundry Co., was announced. In trials one man produced 1200 crawler track links per hr. on this machine; this was in contrast to 275 links per hr. formerly produced by three men on three hand-fed presses. Heating, feeding, forging, and delivery of the finished forgings could be accomplished automatically without assistance from the operator.

The upset forging machine developed in the 1880's has become larger, faster, more powerful and more rigid.

There is not space here to review the hundreds of minor improvements which have increased the productivity of these various machines. However, those listed show there is no stagnation in this industry.

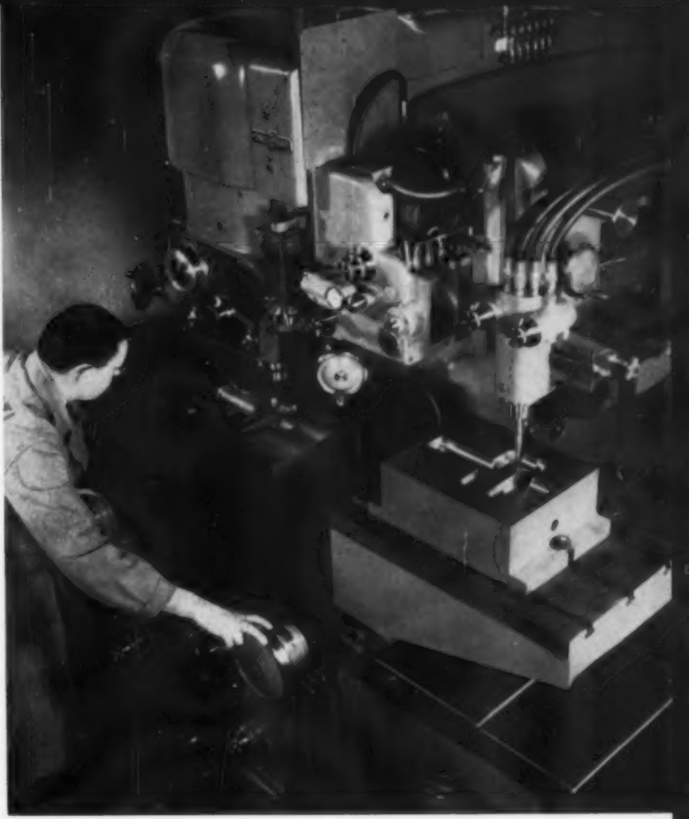


Fig. 4 – Automatic Die-Sinking Machine. After the machinist sets the machine, every operation is automatic. (Courtesy Cincinnati Milling Machine Co.)

Making Dies Automatically

Diemaking was originally a form of sculpture in hard metal. Excess metal was literally hacked out by hand, and machines could do little of the work. Gradually, tools especially designed for machining die cavities were evolved, until skilled machinists could do practically everything but the final dressing. In the early 1900's, automobiles, farm machinery, and other equipment began to be mass produced. The need for hundreds of thousands of identical forged parts gave rise to a similar need for many sets of identical forging dies. This led naturally to the conception of machines which would automatically duplicate a given die impression over and over without a human operator. Gradual progress toward this goal has been going on ever since.

The first development was the tracer-controlled die-sinking machine. First, an accurate model (plastic, wood or metal) of the die impression is made. The tracer on the machine scans the model and guides the cutter to duplicate the impression in the model in the die block being machined. The tracer and cutter move together and must be equally accurate. The first machines were controlled mechanically and did little but rough out the impression.

About 1900, the Keller Mechanical Engineering Corp. (now part of Pratt and Whitney, Inc.) built the first mechanically controlled automatic die-sinking machines. By 1920, the electrical tracer-controlled machine had been designed.

In 1935, Cincinnati Milling Machine Co. introduced a die-sinking machine which was hydraulically controlled. This machine combined automatic depth control with automatic 360° profile tracing in a horizontal plane. All movements (longitudinal, transverse and vertical) were controlled from a single tracer finger. Figure 4 illustrates the machine in operation.

Today, many machine types are available. There are combinations in which two separate tracers are employed simultaneously with two separate masters, and machines which use templets rather than full masters. For simpler dies, many machines only control some of the machine movements automatically.

Many improvements have also been made in hand-operated die-sinking machines. They have become faster, more powerful, more rigid, and

more accurate. Semi-automatic controls have been added so that certain machine movements can be repeated automatically.

New Control Methods

With the recent appearance of electronic computors and allied techniques, new control methods have come into the picture for automatic machining of metals. In "numerically controlled" systems, punched cards, magnetic tape, punched paper tape or the like replace the model. Numerical control begins with a command (coded as numbers on tape or card) to move a machine member or to start or stop some operation. These control systems use "feedback". That is, some type of measuring system determines the exact position of the machine members at all times and feeds this information back to the control system.* Then the system compares input instructions with feedback data and makes corrections if needed.

So far, relatively little work has been done to adapt numerical control to die sinking. Wyman Gordon Co. has an experimental contract with the Air Force to evaluate numerical control versus tracer control for making forging dies. According to them, numerical control looks extremely good for two-dimensional control, but needs more work for three-dimensional control. At present, it takes longer to program a numerically controlled machine than to prepare a model for tracer control, but numerical control provides greater accuracy and speed for the machining operation. Speed is higher because, through proper programing, optimum feed rates and machine speeds can be used at all times. There is hope that programing time can be cut drastically as trained operators become available and as "libraries" of programs are built up for standard shape elements. Maintenance, a headache at first, is now said to be under control.

There is little question but that all the techniques for numerically controlled diemaking are available. Only economics – mainly cost of programs versus cost of models – will determine whether or not numerical control will come into widespread use.

Perhaps the most significant development of all is the research into fundamentals of the forging process itself. Though studies are only beginning, some work has already been done on:

1. The effect of impact and pressure on properties of metal.
2. Metal flow in the plastic state (and the variables that affect it).
3. Studies of die friction, die wear, and lubricants.

These are examples only; the list is by no means as long as it could be.

With regard to the first item, we know that high pressure or impact greatly improves metal properties even in the absence of measurable metal flow.

Fundamental studies of metal flow have been approached from two points of view. The mathematical approach has been taken to determine the geometry of metal flow in relation to the stress system. However, many such studies have considered plastic metal flow in general, rather than any specific working process such as forging. The second approach is the attempt by metal physicists to determine the plastic properties of a metal from its atomic structure.

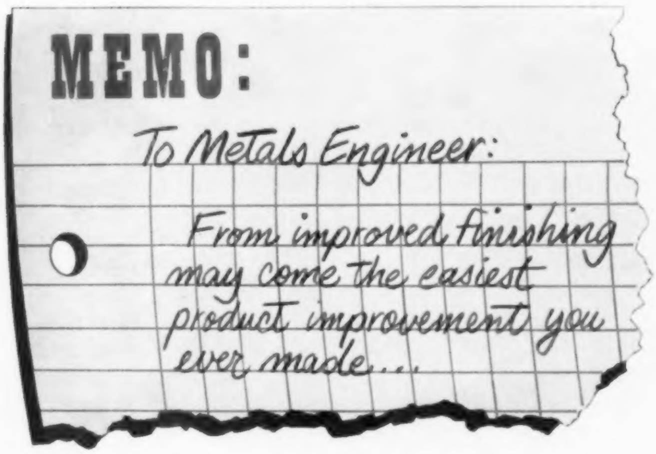
Numerous experimental techniques have been used to study metal flow. As one example, reference grids are marked on the specimen or on the interfaces of composite specimens. Grids are applied before working; deformation is determined by observing the distortion of the grid lines after working. Metal flow can be measured precisely by such methods. In other experiments, drilled holes are plugged with rods of different material, and the specimen is sectioned after forging to show movement of rods.

Other techniques are used; an interesting one for studying cold deformation is to observe the recrystallization behavior after rolling. This is based on the well-known principle that the most highly worked material is the most easily recrystallized. Hardness traverses and other mechanical property studies have also been used to estimate the amount of cold work. In addition, plasticine models, X-ray methods, two-phase alloys, analysis of internal flow from external shape and other techniques have been used.

Many studies have attempted to deal with die friction in a fundamental way. Also several studies of die wear have been made using radioactive tracer techniques.

The surface has only been scratched in studying fundamentals of the forging process. Nevertheless, progress has already been made. Much more should be done and will be done as time goes on.

*In cybernetic language, the machine has "closed loop control" – it is self-correcting. (Hand-operated machines have "open loop" control; feedback is provided by a human operator who measures the output – with micrometers, for example – compares it to a standard and adjusts the machine accordingly.)



No. 2 in a Series on Better Finishing

Grinding and Polishing With Abrasive Belts

By W. K. SEWARD*

With a better understanding of basic principles, production men can put abrasive belts to their best use – keeping productivity high and costs low in many finishing operations. (G18, L10b, W25c; NM-j)

THE PAST FEW YEARS have seen a marked improvement in the performance of abrasive belts. Studies of grinding and polishing methods have shown that definite principles should be followed for best results. Hardness of the workpiece, its shape and size, the area to be ground and polished, amount of material to be removed, finish needed and dimensional tolerances allowed – all are factors which must be considered when choosing the components of an abrasive belt setup. The type of abrasive, contact wheel over which the belt runs, belt speed, lubricant or coolant – these also must be suited to the job because they influence cutting rate and belt life.

The ability of belts to remove metal rapidly is due in part to the uniform distribution of the grain on the backing. Abrasive particles are electrostatically deposited so that their best cutting edges extend away from the belt. Grains are anchored by a thin layer of adhesive which leaves the greater portion of each of them exposed. The other key component which affects the cutting ability of abrasive belts is the contact wheel.

Role of the Contact Wheel

Contact wheels regulate the cutting rate and control the grain breakdown. Breakdown which is too rapid will quickly consume the grain; too slow grain breakdown will result in dulling or glazing and will cut down the stock removal rate. Contact wheel selection can alter cutting rate and belt life by 10 to 500%.

Not all wheels have the same "aggressiveness" – the ability to regulate cutting rate. For example, the simplest way to increase aggressiveness of a smooth contact wheel is to cut equally spaced grooves in its periphery. But other factors such as the hardness and diameter of the

*Supervising Engineer, Coated Abrasives Div., Carborundum Co., Niagara Falls, N.Y.

wheel, the number of grooves, and the ratio of land width to groove width also affect aggressiveness. Production experience and advice of those who deal in abrasive belts will help you select contact wheels to fit a specific job. Once a selection has been made and tried, the results obtained can be used in making adjustments in your grinding practice which will improve performance. Table I (Data Sheet, p. 96-B) suggests measures to correct specific problems.

Types of Contact Wheels

Contact wheels are made of cloth, canvas, leather, fiber, wood, metal, rubber, plastic or combinations of these materials (Fig. 2). Rubber and rubber substitutes make the best contact wheels for average grinding and polishing operations. Other materials may well be best suited for some applications. For example, laminated or sectional buff-type cloth contact wheels are good where maximum wheel flexibility is required. If the operation is such that edge wear of the wheel is high, the outside sections can be replaced at low cost. Compressed canvas wheels can be shaped to conform to a given contour. Metal or metal and rubber wheels are unexcelled for producing close dimensional tolerances and are best when heavy grinding pressures are required. (See Table III, Data Sheet, p. 96-B.)

Out-of-roundness of the contact wheel will have the same effect as an out-of-balance condition – both cause pounding or chattering of the work. Belt life will be reduced, and final finish will be impaired. Dressing the wheel (Fig. 3) at operating speed corrects out-of-roundness.

Types of Backing

Cloth backings for abrasive belts are generally of two types: drills (X weight), which are the heavier and stiffer of the two; and jeans (J weight) cloths, which are quite flexible in comparison. The flexible J-weight backings are used for contour polishing where the abrasive belt and contact wheel must be deformed to follow the contours of the part. However, best belt life and fastest cutting are obtained with the heavy, stiff backing.

The stiffness of the backing can be altered by mechanical flexing or controlled cracking of the bond by the manufacturer. The industry uses two basic types of flexing. With one, the belt is run over bars placed 90° to the direction of travel; in the second, two bars, each placed 45° to the belt direction, are used to crack the bond. Both cracking procedures increase flexibility of the backing.

The type of bonding agent which is used to anchor the grains of abrasive to the backing plays an important part in belt life. There are six common bonds: all-glue, modified-glue, resin over glue, straight resin, synthetic varnishes, and modified resin. They increase in toughness and heat resistance in the order given. The hardness and toughness of the bond must be fitted to the

Fig. 1 – High Productivity of Abrasive Belt Grinding Is Advantageous in Foundry Operations. Quick removal of gate and riser stubs, and parting line fins is needed for economical production

Roughing and Polishing Metals With Abrasive Belts

Table I – Contact Wheel Adjustment Chart
Courtesy of Coated Abrasives Div.,
Carborundum Co., Niagara Falls, N. Y.

Table II – Recommended Grit Size, Belt Speed, Lubricant and Contact Wheel Type
Compiled by Robert I. Chard,
Behr-Manning Co., a division of Norton Co., Troy, N. Y.

Table III – Contact Wheels and How They Work
Also Courtesy of Behr-Manning Co.

Table I—Contact Wheel Adjustment Chart

Result Obtained	Suggested Changes											
	Softer	Harder	Narrower Lands (Wider Grooves)	Wider Lands (Narrower Grooves)	Higher Speed	Lower Speed	Change Lubricant	Deeper Grooves	True Wheel	Use Coarser Grit	Use Finer Grit	Check Machine Condition
Belt glazed		X	X			X	X					
Belt loaded	X		X				X	X				
Too slow cutting		X	X			X	X			X		
Finish too coarse				X	X		X				X	X
Burning		X	X			X	X			X		
Too hard for contour	X		X			X		X				
Chatter	X		X					X	X			X
Shedding grain		X		X		X	X		X			
Dubs edges		X	X									

Note: All of the suggested changes checked for a given condition may not be necessary.

Table II—Recommended Grit Size, Belt Speed, Lubricant and Contact Wheel Type

Material	Operation	Grit	Belt Speed, Sfpm.	Lubricant*	Contact Wheel Type	Contact Wheel Hardness†
Hot and cold rolled steel	Roughing *(a)*	24–60 X	4000–6500	Dry or light-bodied grease, sulphur-chlorinated oil spray	Cog-tooth, serrated rubber	70–90
	Polishing *(a)*	80–150 X	4500–7000	Dry or light-bodied grease, sulphur-chlorinated oil spray	Plain-faced or serrated rubber sectional, X-serrated rubber or free belt	20–60
	Fine polishing *(a)*	180–500	4500–7000	Heavy grease or grease with abrasive compound	Plain-faced rubber or cloth	20–40
Stainless steel	Roughing *(a)*	50–80 X	3500–5000	Light-bodied grease or sulphur-chlorinated oil flood	Cog-tooth, serrated rubber	70–90
	Polishing *(a)*	80–120 X	4000–5500	Light-bodied grease or sulphur-chlorinated oil spray	Plain-faced or serrated rubber sectional, X-serrated rubber or free belt	30–60
	Fine polishing *(b)*	150–280	4500–5500	Heavy grease or oil mist	Plain-faced rubber or cloth	20–40
Aluminum, cast or fabricated	Roughing *(c)*	24–80 X	5000–6500	Light-bodied grease or sulphur-chlorinated oil spray	Cog-tooth, serrated rubber	70–90
	Polishing *(c)*	100–180	4500–6500	Light-bodied grease or sulphur-chlorinated oil spray	Plain-faced or serrated rubber sectional, X-serrated rubber or free belt	30–50
	Fine polishing *(c)*	220–320	4500–6500	Heavy grease or grease with abrasive compound	Plain-faced or X-serrated rubber or free belt	20–50
Copper alloys or brass	Roughing *(c)*	36–80 X	2200–4500	Light-bodied grease or sulphur-chlorinated oil spray	Cog-tooth, serrated rubber	70–90
	Polishing *(c)*	100–150	4000–6500	Light-bodied grease or sulphur-chlorinated oil spray	Plain-faced or serrated rubber sectional, X-serrated rubber or free belt	30–50
	Fine polishing *(c)*	180–320	4000–6500	Light-bodied grease or grease and abrasive compound	Same as polishing	20–30
Nonferrous die castings	Roughing *(c)*	24–80 X	4500–6500	Light-bodied grease or sulphur-chlorinated oil spray	Hard wheel depending on application	50–70
	Polishing *(c)*	100–180 X	4500–6500	Light-bodied grease or sulphur-chlorinated oil spray	Plain rubber, cloth or free belt	30–50
	Fine polishing *(c)*	220–320	4500–6500	Heavy grease or grease with abrasive compound	Plain face or X-serrated rubber or free belt	20–30
Cast iron	Roughing *(a)*	24–60 X	2000–4000	Dry	Cog-tooth, serrated rubber	70–90
	Polishing *(a)*	80–150 X	4000–5500	Dry	Serrated rubber	30–50
	Fine polishing *(a)*	120–240 X	4000–5500	Dry	Smooth-faced rubber	30–40
Titanium	Roughing *(c)*	36–50 X	700–1500	Sulphur-chlorinated grease stick or oil flood	Small diameter, cog-tooth serrated rubber	70–80
	Polishing *(b)*	60–120 X	1200–2000	Light-bodied grease	Standard serrated rubber	50
	Fine polishing *(b)*	120–240 X	1200–2000	Light-bodied grease	Smooth-faced rubber or cloth	20–40
High-temperature alloys ‡	Roughing *(a)*	24–50 X	4000–5500	Sulphur-chlorinated grease stick	Smooth-faced steel or cog-tooth serrated rubber	70–90
	Polishing *(a)*	40–100 X	4000–5500	Light-bodied grease	Serrated rubber	50
	Fine polishing *(a)*	100–150 X	4000–5500	Light-bodied grease	Smooth-faced rubber	30–40
S-816	Roughing *(a)*	24–50 X	4000–5500	Sulphur-chlorinated grease stick or oil spray	Smooth-faced steel or cog-tooth serrated rubber	70–90
	Polishing *(a)*	40–100 X	4000–5500	Light-bodied grease	Serrated rubber	70
	Fine polishing *(a)*	100–150 X	4000–5500	Light-bodied grease	Smooth-faced rubber	50

* Unless removed immediately after the grinding operation, sulphur-chlorinated lubricants may stain the workpieces. Emulsions and rust-inhibited water coolants are recommended when overheating of workpieces is a problem.

(a) Aluminum oxide is preferred abrasive.

(b) Silicon carbide is preferred abrasive.

(c) Both abrasives are satisfactory.

† Durometer scale. The Durometer reading is a measure of rubber hardness.

‡ Inconel X, Inconel 700, Nimonic 80, Nimonic 90, Nimonic 100, Stellite 27, Waspaloy, Hastelloy

Table III—Contact Wheels for Abrasive Belts and How They Work

Wheel	Surface	Material	Hardness and Density	Purposes	Wheel Action	Applications
	Cog-tooth	Rubber	70–90 Durometer	Grinding	Fast cutting, allows long belt life.	For cutting down projections such as weld beads gates risers, sprues.
	Standard serrated	Rubber	40–50 Durometer, medium density	Grinding	Removes stock but leaves rough to medium ground surface.	For smoothing or blending projections or surface defects.
	X-shaped serrations	Rubber	20–50 Durometer	Grinding and polishing	Flexibility of rubber allows entry to contours. Medium polishes and light stock removal.	Same as standard serrated wheels but preferred for softer, nonferrous materials.
	Plain face	Rubber	20–70 Durometer	Grinding and polishing	Plain wheel face allows controlled abrasive grain penetration.	For large or small flat faces. Soft wheels give good finishes.
	Flat flexible	Compressed canvas	Nine densities going from hard to soft	Grinding and polishing	Hard wheels cut more slowly than cog-tooth rubber wheels.	Good for medium-range grinding and polishing. Soft wheels polish to fine smoothness.
	Flat flexible	Solid sectional canvas	Soft, medium and hard	Polishing	Gives uniform polishes. Avoids abrasive pattern on work. Adjusts to contours. Can be preformed for contours.	A low-cost wheel with uniform density at the face. Handles all types of polishing.
	Flat flexible	Buff section canvas	Soft	Contour polishing	For fine polishes and finishing.	Can be widened or narrowed by adding or removing sections. Low cost. For all types of polishing.
	Flat flexible	Sponge rubber inserts	5–10 Durometer, soft	Polishing	Gives uniform polishes and finishes. Polishes and blends contours.	Has replaceable segments. Polishes and blends contours. Segments allow density changes.
	Flat flexible	Rubber segments	Varies in hardness	Grinding and polishing	Grinds or polishes depending on density and hardness of inserts.	For portable machines. Uses replaceable segments that save on wheel costs and allow density changes.
	Flat flexible	Inflated rubber	Air pressure controls hardness	Grinding and polishing	Gives uniform finishes.	Adjusts to contours.

Fig. 2 — Contact Wheels Determine Performance of Abrasive Belts. Each is designed to regulate the cutting rate of belts in specific grinding and finishing jobs

type of operation being performed. In polishing operations which require light pressure, an all-glue or modified-glue bond is best. As stock removal requirements and grinding pressure increase, the harder and tougher bonds should be selected. Water can be used to lubricate any of the belts bonded with synthetic varnish.

The correct treatment of belt trouble requires an understanding of glazing and loading. These troubles point to incorrect components or procedures. The recognition of glazing and loading can lead to lower polishing costs because both defects result in early discarding of belts even though there is plenty of abrasive left.

Glazing occurs when insufficient grinding pressure is used or when the contact wheel is not aggressive enough to produce controlled grain breakdown. The tips of the grains wear smooth and become shiny through friction and sliding contact with the work. Corrective action calls for the use of a harder contact wheel or more grinding pressure to remove the shiny surface by fracturing the abrasive particles. Only then will new cutting edges be exposed. There is no need to throw away glazed belts, but it is best to correct the cause.

Loading looks like glazing and the two defects are often confused with each other. On a loaded belt, metal becomes smeared over or welded to the grains. It is most pronounced when a soft metal is being ground or when the part has a low thermal conductivity. There are plenty of sharp abrasive grains on loaded belts but their cutting ability is impaired by the smeared metal. Unless corrective action is taken (see Table I) belt life will be short and productivity low — your polishing costs will climb.

Lubrication of belts is one way to prevent loading. A lubricant increases the cutting rate

Fig. 3 — Dressing Contact Wheels Which Are Out-of-Round Will Result in Longer Belt Life and Better Finishes. Wheel should be dressed at its operating speed

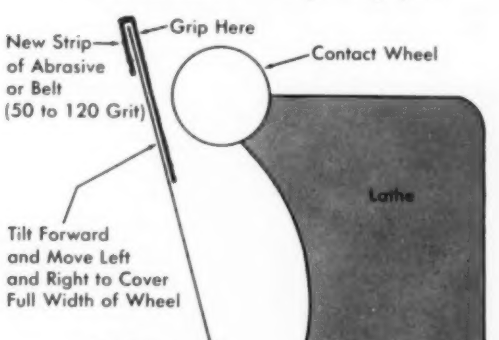


Fig. 4 — Brass Cases Are Given Final Finish in This Conveyer Belt Setup. Operation is continuous and cases are loaded in the holding fixtures while the conveyer belt is moving

and extends belt life by as much as six times that obtained when none is used. Of the three common types of lubricants—stick grease, oils, and water — the stick grease is more popular. It is convenient to use and effective when the metal particles are lightly attached to the abrasive. Grinding and machining oils, however, do a better job when severe loading is a problem. If the parts being ground or polished must be constantly cooled, water-soluble coolants which contain sulphur and chlorine compounds perform best.

Belt Speed

Laboratory and service tests show that the most effective speed for resin-bonded belts is 4000 to 7000 surface ft. per min. (sfpm.). Glue-bonded belts perform best at about 1000 sfpm. lower than those recommended for resin bonds. Generally, the harder the metal, the lower the belt speed. Low speed should be used with coarse grit sizes (60 or coarser); and, on the same metal, higher speeds are recommended when polishing with fine-grit belts (80 or finer).

Platen Grinding for Flat Surfaces

Flat surfaces can be rapidly obtained by grinding against a belt supported by a flat platen. Platen grinding is most successful if the metal is free cutting and if the part has a small or interrupted area of contact with the belt. Belt life and rate of cut are a function of the area being ground on platen operations. If the length of work in the direction of belt travel is greater than about ½ in., chip interference between belt and work greatly reduces the rate of cut and belt life.

Few people know that abrasive belts, like grinding wheels, can be dressed to maintain their cutting ability. Dressing is effective on belts of coarse grit (24 to 60) which have been used in platen grinding. The platen does not afford controlled grain breakdown as does a contact wheel and belts become glazed. Rather than discard the belt, life can be renewed by breaking down the grains with a star dresser.

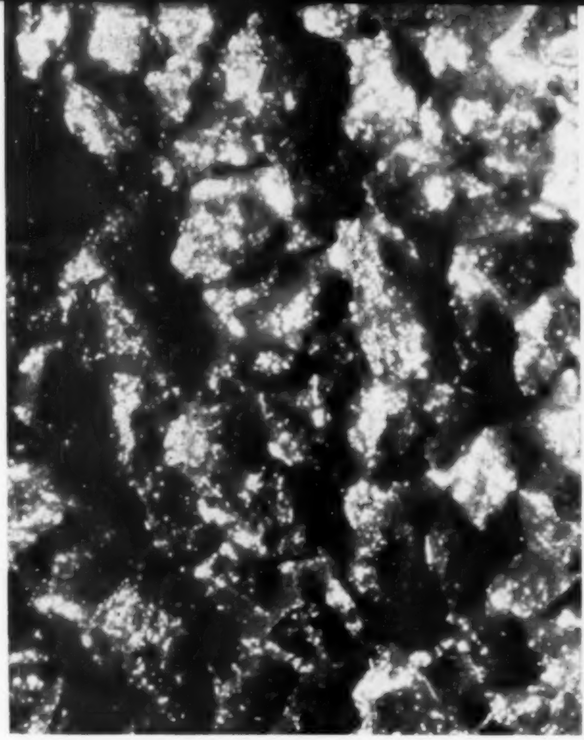
Dressing of belts which are used on contact wheels is not recommended. The function of a contact wheel is to regulate grain breakdown to expose sharp cutting edges. Thus, glazing on belts running on contact wheels is an indication that an improper wheel is being used. Long-range economy dictates corrective action suggested in the Data Sheet on p. 96-B.

Tolerances of ± 0.001 in. are readily held on many through-feed or conveyerized operations even when substantial stock removal is necessary. When fine grit sizes and light grinding pressure are used, tolerances in the range of ± 0.0005 in. are practical on a production basis. On other types of operations, such as roll grinding and centerless grinding, with suitable equipment, tolerances in the range of ± 0.0005 in. are relatively easy to hold and an over-all tolerance of ± 0.0001 in. has been obtained where the equipment was in excellent condition.

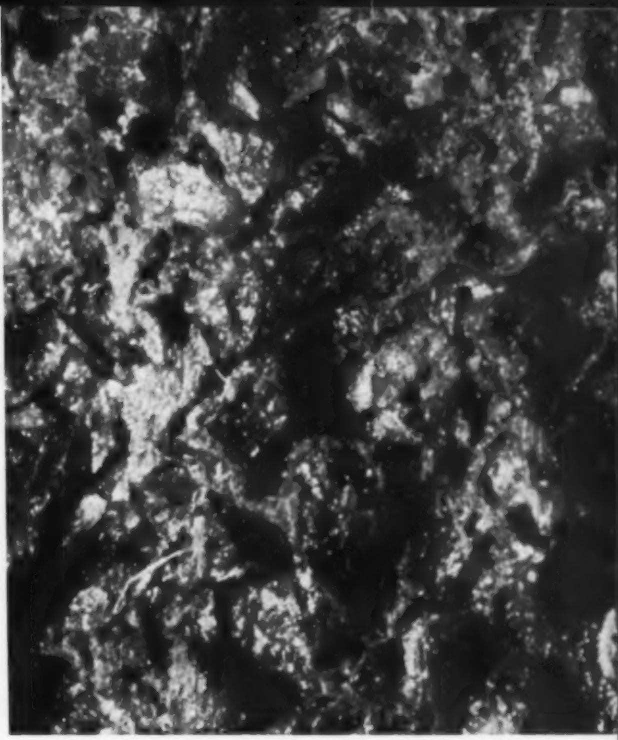
Nonferrous Metals

Most of the nonferrous metals are easily ground and polished with good belt life. It is not uncommon for coarse-grit belts, 3 to 4 in. wide, to remove over 100 lb. of metal before wearing out. The same belt would remove only 10 to 15 lb. of ferrous metal.

Loading is the most serious problem with nonferrous metals. Ductile materials are the worst



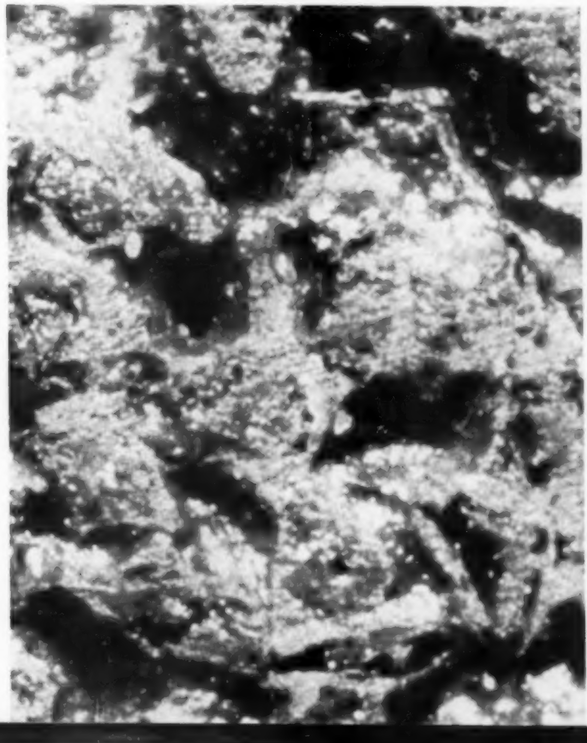
New Belt of 36-Grit Aluminum Oxide Bonded With Resin. Properly chosen contact wheels and lubricants will insure controlled grain breakdown without loading and glazing. 16 ×



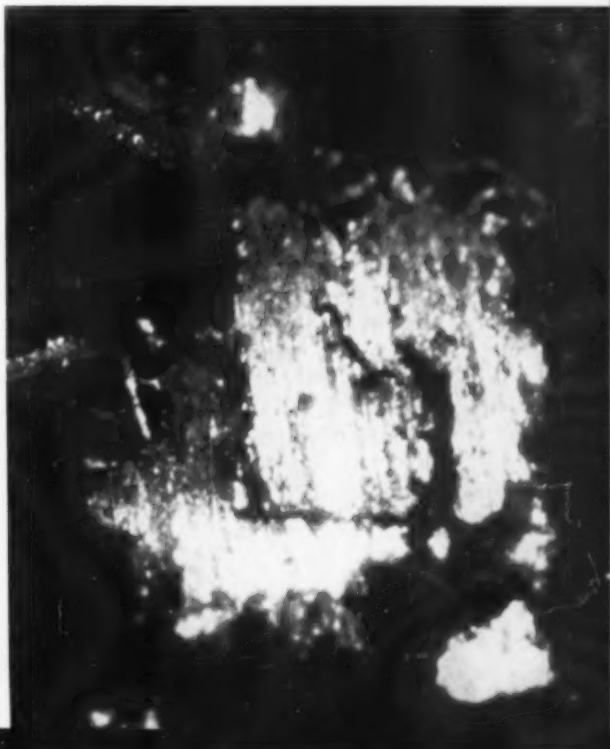
Used 36-Grit Aluminum Oxide Belt Showing Rapid Grain Breakdown. Dark areas are craters where abrasive grains have been pulled out of the bond. The contact wheel used with this belt was too hard. 16 ×

Microscope Pinpoints Production Problems in Belt Polishing

Surface of a Glazed Belt. Tips of grains have been worn smooth because inadequate grinding pressure or a soft contact wheel was used. Cutting rate is greatly reduced. This belt can be saved by switching to a more aggressive contact wheel or applying heavier pressure. 45 ×



Loading Occurs When Metal Becomes Smeared and Fused on the Tips of the Abrasive Grains. Note inadequate grain breakdown and pull out. Cutting edges have been covered and no new ones exposed. Best cure is lubrication or a harder contact wheel. Both may be required. 45 ×



offenders, but lubricants will minimize the problem. During hand operations when coarse grit sizes are used for rough grinding, lubricants may not be needed if the metal is hard and has good machinability. Some of the soft metals require application of grease of high melting point only when the belt is new; others require repeated applications of the grease. When a lubricant is needed, it should be applied to the belt before any grinding is done to prevent loading. Once the belt has become loaded no lubricant will restore its original sharpness.

Productivity during rough polishing with coarse grits and heavy pressure (2 hp. or more per in. of contact width) is higher when aluminum oxide rather than silicon carbide abrasives are used. When grit sizes between 24 and 120 are used with light pressure for rough polishing operations, silicon carbide grain will cut more rapidly and last longer than aluminum oxide. Aluminum oxide performs best in fine-grit polishing (150 and finer).

Mechanized operations perform most efficiently when a flood of compounded oil is used. Best flushing of chips and cooling of the work is obtained with light viscosity oils in the range of 80 to 150 SSU*. Paraffin-base mineral oils which contain 10% lard oil do a good job.

Neither oil nor water lubricants are as convenient to use as are grease sticks, but both are useful when particular problems arise. A flood of oil maintains cutting ability and gives longer belt life than other lubricants. Water has the best cooling ability and is recommended when overheating is a problem.

Tough bronzes and nonferrous materials such as Monel and Inconel should be treated the same as stainless metals.

Ferrous Metals

Aluminum oxide is used almost exclusively for grinding and polishing ferrous metals. One exception is in final finishing of stainless sheet. Here silicon carbide imparts a brighter surface with a slight bluish cast which is good for decorative purposes. The ease of grinding or polishing ferrous metals is related to machinability. Thus, leaded steels, which machine freely, are easily ground; hardened nickel steels are more difficult to machine and are also more difficult to grind.

Where a large amount of metal must be removed, it is most economical to use a hard contact wheel. The size, speed and aggressiveness of the contact wheel must, of course, be fitted to the particular job. For example, very hard materials or those which are covered with scale require a harder (90 durometer) and more aggressive wheel than unhardened metals with clean surfaces. When scale must be removed from contoured surfaces, it is better to use a wheel which is too hard than one which is soft enough to conform to the contours. True, the hard wheel may give an excessive cutting rate and cause flat spots, but belt life will be good. Flat spots can be blended out by a softer wheel after the scale is removed.

Lubrication is often vital but may be overlooked as a step to effective grinding and polishing. In grinding stainless steels, loading of belts is a problem but oils containing sulphur or chlorine antiweld compounds increase belt life. Generally, high alloys with greater toughness require more antiweld additives in the oil. On such materials a flood of oil is more effective than a mist or spray.

When loading is a problem in the nonstainless metals, a change to a harder and more aggressive contact wheel may be all that is required. This may even eliminate need for a lubricant.

Know Belt Limitations

While belts can do many operations faster and more economically than other methods, they are by no means a universal tool for all types of finishing operations. Obviously, a belt cannot be used for cutting. It is not economical to use belts for cleaning off fins when they occur in small radii, next to shoulders, or in right angles of castings and forgings. Grinding in these areas requires use of the edge of the belt and damages the cloth backing and the edge of the contact wheel. Grinding sharp projections such as fins is practical when the entire surface can be used.

Close-tolerance grinding with belts near shoulders, flanges, and changes in diameters is not recommended. The strength of the backing also limits the use of belts for severe grinding where levers and other mechanical aids run pressures higher than 5 to 6 hp. per in. of contact width. Like all tools, successful application of belts depends on proper choice of components. Choose the grade of abrasive, type of contact wheel, and lubrication to fit the job. Recognize the signs of inefficient performance in your grinding and polishing operations. The corrective measures you apply will help you achieve best results from abrasive belts – low-cost operation and a better finish for your product.

*Seconds Saybolt Universal.

Steelmaking on the Move

Potential for Oxygen in Steelmaking

*Special Report by E. C. WRIGHT**

Companies using the oxygen converter process and those experimenting with oxygen in blast furnace and openhearth report economies and increased production rates. Future need for more steel capacity at reasonable cost is expected to spark a boom in oxygen steelmaking techniques. (D-general, D10; O)

In 1958, THE STEEL INDUSTRY used 28.8 billion cu.ft. of oxygen, an 11% increase over the record set in 1957. This increase occurred even though the steel industry operated at only 60% of capacity in 1958. (It operated at 84% in 1957.) Of the 28 billion cu.ft., 13 billion was used for steelmaking and 5.9 billion was used in blowing blast furnaces, according to *Steel Facts*, published by the American Iron and Steel Institute.

The total capacity of American steel mills in 1958 is given as 140,742,570 tons. If this total capacity were treated with oxygen in either the openhearth, electric furnace or oxygen converter, nearly 140 billion cu.ft. of oxygen would be needed. This approximates 5.82 million tons of oxygen. It is evident that the steel industry is only using about one fifth the oxygen that might be used for increasing steel production.

Again, according to American Iron and Steel Institute figures, the steel industry purchased 15,610 million cu.ft. from outside suppliers in 1958, while it produced only 5,559 million cu.ft. Apparently, only oxygen converter plants have their own oxygen plants. A 300 ton-per-day oxygen plant in a converter operation will produce about 1.5 million tons of steel in a year. Furthermore, in the 1957 to 1959 period the capacity of oxygen-blown converter plants has increased from about 500,000 tons to 4 million tons per year. (Several new plants of this type are in the estimating stage.) Converter steel capacity, 4 million tons in 1959, will consume over 6 billion cu.ft. of oxygen per year.

The figures given above only consider steel manufacturing. If the use of oxygen in the blast furnace develops, which seems possible, the amount of oxygen required in a steel plant would be tremendous. An ordinary blast furnace uses about 100,000 cu.ft. of air per ton of pig iron produced, and if this air is increased from 21% oxygen (normal air) to 23½% oxygen (enriched air), the amount of oxygen required becomes fantastic. Since there are 91 million tons of blast furnace capacity in the United States today, enrichment of the blast to 23½% would require about 225 billion cu.ft. of oxygen. If this is added to the 140 billion cu.ft. required for steel production, a total consumption of 365 billion cu.ft. of oxygen is obtained. This does not include the oxygen used in combustion in the openhearth and several other applications. Potentially, this amount of oxygen might be used in the blast furnace and steel-melting industry in the future. Since only 28.8 billion cu.ft. of oxygen was used in 1958, the potential for added oxygen capacity becomes enormous. There might be an eventual requirement for 500 billion

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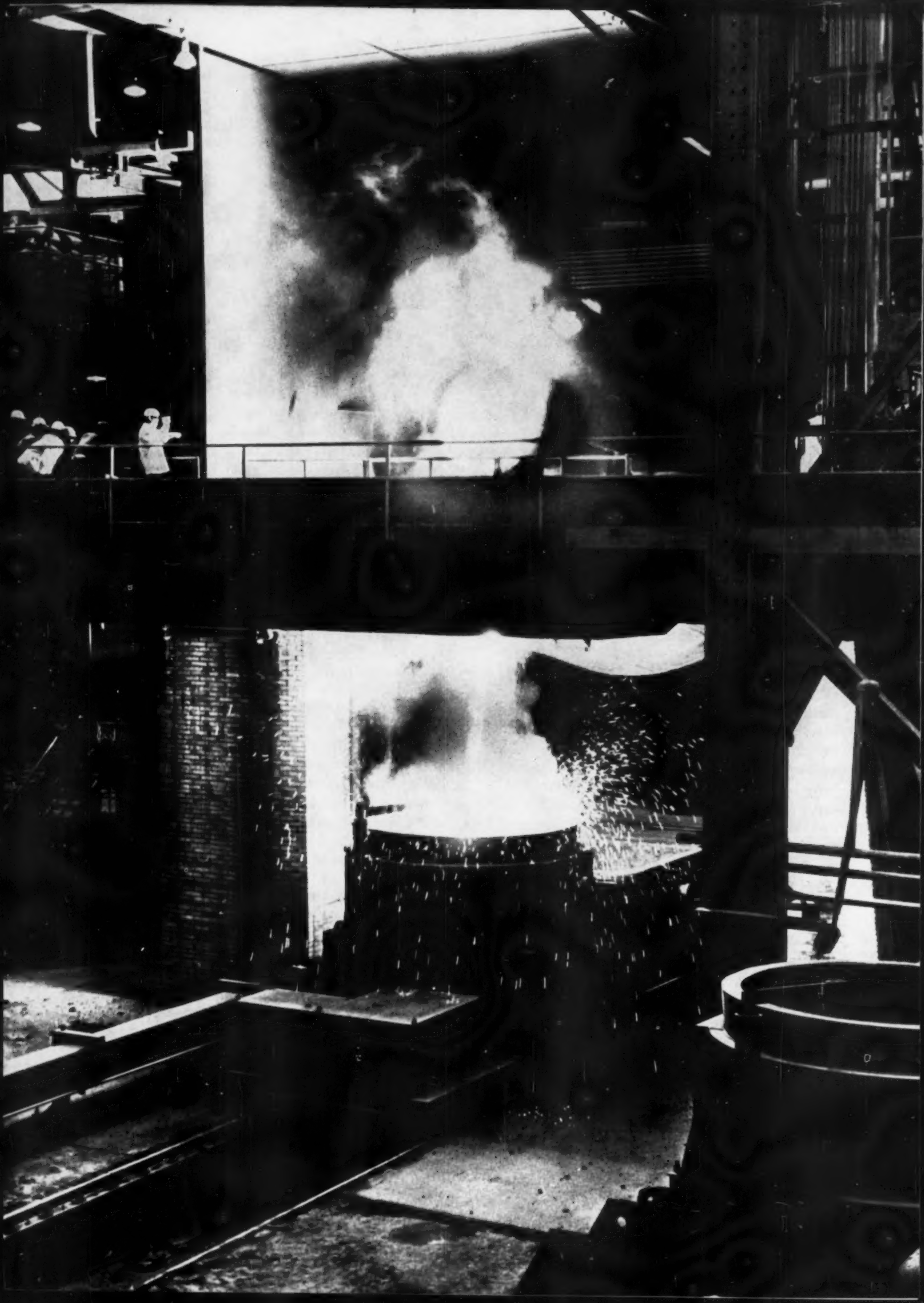


cu.ft. of oxygen; this amounts to 20,000,000 tons.

In an article in *Blast Furnace and Steel Plant*, May 1959, H. B. Emerick, technical director, Jones & Laughlin Steel Corp., listed the places where oxygen could be used to advantage in a steel plant. According to him, blast-furnace gas can be enriched to over 21% oxygen to reduce ore to metal, oxygen can be used to produce hydrogen for direct ore reduction, and metal from the blast furnace can be desiliconized before charging into the openhearth furnace. Also, oxygen can be used in the openhearth (to decarburize or enrich the air used for combustion to raise flame temperatures) and in the electric furnace (especially on stainless steel for decarburization). Finally, he mentions pneumatic processes. Bottom-blown converters or overhead injection L-D converters can use a good deal of oxygen.

In the steel industry, all these different methods are being employed, mostly on an experimental basis, to determine the effectiveness of oxygen in any given situation. All reports, up to the present time, indicate that oxygen definitely increases iron production in blast furnaces and steel production in openhearths and converters. These increases in production are of great value because less equipment (and, thus, less capital investment) is needed to increase production. Since steel capacity increases in the United States at about 4 million tons per year, these reported increases in production due to oxygen application are of great importance.

The use of oxygen reduces coke consumption in the blast furnace, and fuel, ore and lime consumption in the openhearth. Also, more scrap is melted in the converter without fuel. The decrease in material and labor costs, due to increased production per hour, must be balanced against the cost of oxygen. No one will commit himself as to the cost of oxygen, since it varies with the purity, size of oxygen plant, and whether it is purchased from one of the large oxygen producers. The only sensible figures supplied the writer are about $0.50 per ton in an L-D converter using 1500 to 1600 cu.ft. of oxygen per ton of steel, and $0.30 per ton in an openhearth using 700 to 800 cu.ft. per ton. This cost is certainly compensated for by the savings in labor, fuel, refractory and capital costs that result from use of oxygen.

The results obtained with the L-D process,

New Oxygen Converter on West Coast Pours Test Heat. (Courtesy Kaiser Steel Co.)

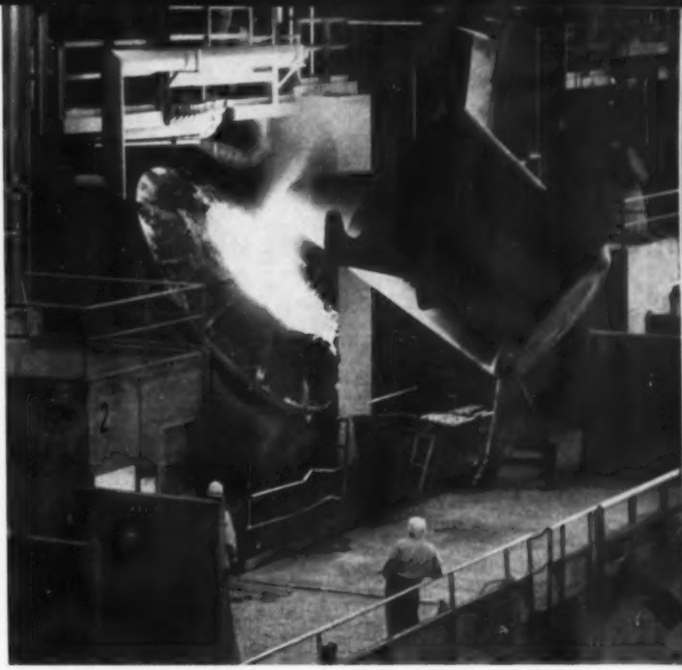


Fig. 1 – Oxygen Converter Being Charged With Molten Pig Iron. After subsequent charging with scrap and lime, a jet stream of oxygen refines the steel in less than 30 min. (Courtesy Kaiser Steel Co.)

since its first installation in Canada in 1954, have been spectacular. Steelmakers have been surprised to learn that almost any type of steel can be produced in this operation. Both high and low-carbon steel (ranging from 0.05 to 1.00% C) have been produced satisfactorily. Europeans even make 52100 and other alloy grades. In the United States, work has been confined to carbon steel grades, and nearly every heat has been applied as originally scheduled. In blowing, it has been possible to catch the carbon content on the way down at any level from 1.00 to 0.05%. This is usually done by blowing a constant oxygen for a definite time, or blowing to a lower carbon content and recarburizing to the desired carbon content before tapping.

One of the most surprising results of the L-D process has been the low phosphorus and sulphur contained in the heats. In general, amounts are definitely lower than can be reached in the openhearth furnace, and the resulting steel has been rolled much better than openhearth steel. For example, one company reports for a month's operation on the L-D converter an average of 0.01% P, 0.015% S, and 0.003% N.

Steel metallurgists probably have not realized the importance of this low sulphur content because they have had to live with 0.03 to 0.05% S from the average openhearth heats. The influence of sulphur in minute amounts in steel has

been emphasized by some other work, where sulphur content has been reduced to 0.007% in experimental heats. Compared to steel with 0.025 to 0.04% S, this low-sulphur material has great ductility at forging temperatures. On strip steel rolling, there is less edge cracking, and in seamless tube manufacture – a difficult piercing operation – seaminess is much lower.

As to theory, it is quite possible that the high temperatures reached during operation of the oxygen converter reduce some of the magnesium oxide, which makes up 50% of the lining. Magnesium has a very potent effect in the desulphurizing of iron and steel.

Converter Construction

Oxygen converters are built in sizes from 14 to 20 ft. O.D., and 25 to 35 ft. in height. The outside is usually made of plate 2 in. thick, while the inner lining consists of about 4 in. of magnesite brick. This is called the permanent lining and weighs 30 to 50 tons for a 50-ton vessel. The working lining usually consists of magnesia dolomite brick about 16 to 18 in. thick. Bonded with tar and weighing 100 to 150 tons, this lining generally contains 30 to 50% MgO. It wears out very rapidly as blowing proceeds. The life of an average lining is only about seven days, and anywhere from 180 to 250 heats may be made, depending upon the size of the vessel.

The working volume of a 50-ton vessel is 1150 cu.ft. when the lining is new, but this increases to about 1650 cu.ft. as the lining erodes. Obviously, the size of the hot metal charge increases as the lining wears. The ordinary plant has two or three converters, one of which is always being lined while the others may be in operation. It takes about five days to reline a vessel, so a plant with two converters would have one vessel operating and the other vessel being relined. At two different plants, the amount of refractory used per ton of steel is about 20 lb. Thus, refractory cost is much lower than in the openhearth.

The production of steel in these converters has been increased every year, and the end is not in sight. One plant with a 65-ton converter started out by producing 1400 tons per day. This has since increased to 3200 tons per day, which amounts to over a million tons per year for this converter. Average production rate per hour was 83.2 tons, which is at least two times as much as produced in the most modern openhearth furnace using oxygen.

The rate of production and the temperatures reached in an oxygen converter differ with the rate of blowing oxygen, the amount of combustible impurities in the pig iron and the amount of cold scrap added as a coolant. Silicon is the greatest producer of heat, and about 25% scrap can be charged with about 1.00 to 1.25% Si. Oxygen blowing rates vary greatly, ranging from 3000 to 6500 cu.ft. per min. The temperature rises more rapidly as the rate of oxygen blowing increases. One company now blowing 6500 cu.ft. per min. is able to melt at least 30% scrap with a normal silicon content.

The oxygen must be about 99.5% pure, and the pressure about 150 psi. It is introduced through a long water cooled lance which has a water cooled copper casting on the lower end. This lance may be located at any level above the bath and retracted as desired for tilting the vessel. A projected new converter of 160 tons will probably have a blowing rate of 10,000 cu.ft. per min.

Growth of Oxygen Converter

In the last six years 31 plants have been built all over the world. These plants are distributed in the following countries:

Country	No. of Plants	No. of Converters
Austria	2	7
Belgium	2	4
Brazil	2	5
Canada	2	5
Finland	1	2
France	1	2
West Germany	3	5
India	1	3
Japan	5	10
Portugal	1	2
Spain	2	3
United States	4	12
U.S.S.R.	5	about 10

This gives one an idea of how this process has been accepted in most steelmaking countries.

Bottom-Blown Basic Converter

All of the bottom-blown vessels in the United States are acid lined and are now very little used except for screw stock and other specialties. Steel from these vessels is high in phosphorus (about 0.10%) and nitrogen (about 0.015%). There are no basic-lined converters in the United States.

The Western European countries such as Germany, Belgium, France and Luxemburg have made more than half their steel in basic converters which are bottom-blown with air. These vessels make a high-nitrogen steel, and specifica-

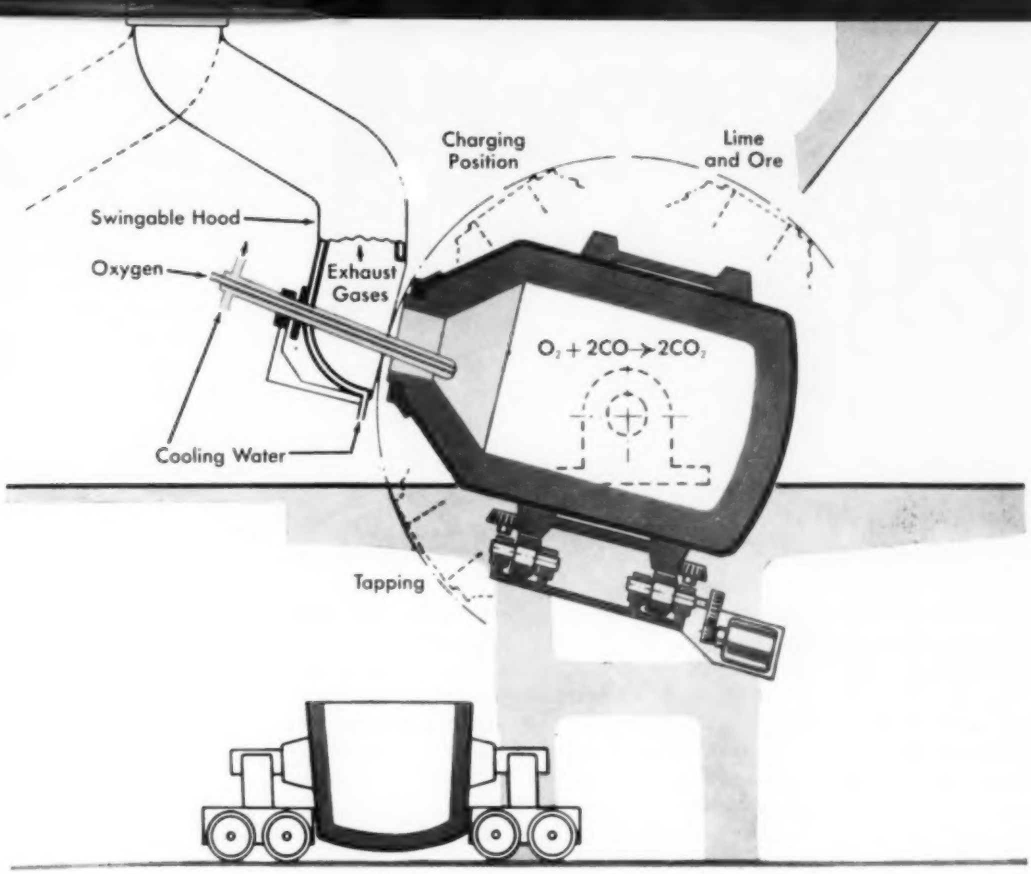


Fig. 2 – Diagram of Stora-Kaldo furnace in Operation at Domnarvet. The converter spins 10 to 30 times a minute while oxygen is being inserted. Reduction of impurities is very rapid. (Courtesy Dravo Corp.)

tions have become so rigid in respect to nitrogen that this method of making steel almost became obsolete. However, by using various amounts of oxygen, all of these plants have been revived and steel containing 0.008% N along with low phosphorus is now being successfully produced. This change was effected by blowing air enriched with up to 28% oxygen. Since the hot metal being blown does not take up nitrogen as long as the carbon is not over 1.0%, the nitrogen content does not increase. Final decarburizing and dephosphorizing are achieved by blowing with about 50% oxygen and 50% steam with no nitrogen in the blast. The Western Europeans claim that steel made in this way is comparable to openhearth steel. There are many variations of these practices, but they all have about the same results.

Another innovation in oxygen converters was developed by the Swedes, the so-called Kaldo process. In this method, a rotating converter inclined at an angle of about 17° (see Fig. 2 and 3) is rotated around the central axis at from 10 to 30 rpm. Oxygen is blown into the vessel much as it is in the upright oxygen blown converter, but the rotation of the vessel mixes the slag thoroughly, and phosphorus removal is most rapid. In this vessel, the Swedes have handled hot metal with 0.15 to 2.0% P. When the phosphorus rises above 0.50%, the double slag process is necessary. Units up to 25 tons capacity have been put in operation in three different countries.

The use of oxygen for refining in the openhearth furnace is still in its infancy. As far as can be learned, only about two shops containing 20 furnaces are using oxygen in all the furnaces. There are over 900 openhearth furnaces in the United States, and nearly every steel plant is experimenting with the use of oxygen.

An openhearth furnace with a 50% hot metal and 50% scrap charge requires about 800 cu.ft. of oxygen per ton to refine the impurities out of the hot metal. This is about half of that used in the oxygen-blown converter. Some of the oxygen needed in the openhearth is supplied by oxidation of the scrap charge, oxygen contained in the furnace gases, and oxygen obtained from the limestone and ore charge. If the maximum amount of oxygen, 800 cu.ft. per ton, is used, an ore charge is not needed. Results obtained with oxygen blowing in the openhearth show

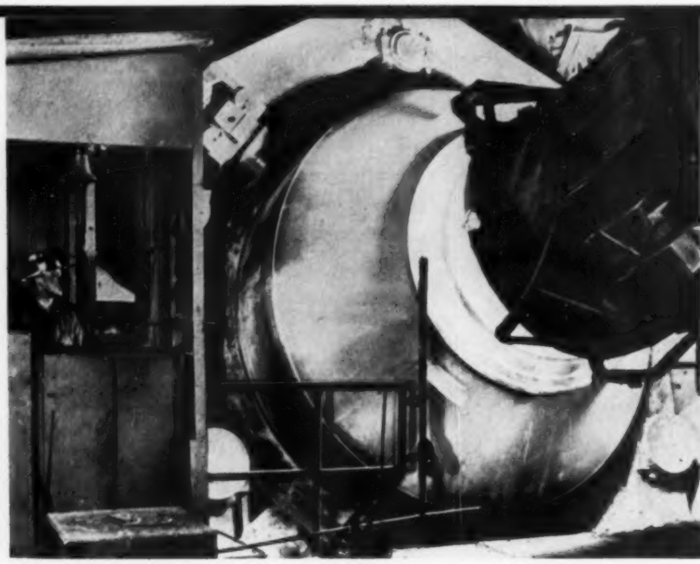


Fig. 3 – Stora-Kaldo Furnace in Action (Courtesy Dravo Corp.)

about 30% increase in tons per hour. Less lime, fuel and ore are used.

The plants visited were using anywhere from 130 cu.ft. to a maximum of 760 cu.ft. per ton, so the practice varies greatly, mainly due to a limited oxygen supply. If oxygen is used immediately after charging scrap, the bath temperature is raised and the rate of melting is increased. In a 300-ton furnace which produces about 30 tons of steel per hr., oxygen can increase production to about 40 tons per hr. In certain instances, oxygen-blown openhearths can produce 50 tons per hr., but the average in these plants using the maximum amount of oxygen was about 39 tons per hr.

In a large furnace, oxygen is usually introduced by a lance thrust vertically through the roof from both sides. Flow rates are about 40,000 to 50,000 cu.ft. per hr. Of course, oxygen cost must be balanced against the faster melting time, reduced ore and lime charges. Such calculations appear to favor the oxygen practice. If oxygen can increase openhearth production by 30%, the life of these furnaces can be greatly prolonged and capital investment costs for new production can be greatly reduced. Naturally, new capital for oxygen plants, and dust and fume control equipment would be needed.

The use of oxygen injection in openhearth furnaces has greatly changed their refractory requirements. Temperatures as high as 3100° F. are attained and the old silica roofs cannot stand these conditions. Furthermore, the large amount of iron fume also attacks silica refractories. As a result, practically all the openhearth furnaces using large amounts of oxygen have needed basic roofs. These have been standardized on magnesite chrome brick. In addition, the ends and slag pockets are usually lined with basic bricks, because of the large amount of iron fume that develops.

Out of some 900 openhearth furnaces in the United States, there were about 103 with all-basic roofs in January 1959. This is an increase from only six basic roofs in 1956. The actual number of all-basic roofs is hard to estimate because some are now being built, while bricks have been ordered for others. Close to 200 all-basic furnaces are expected by 1960. Contrast this to Europe. There, basic furnaces have been used for 25 years, and most of the furnaces in Western Europe are now of all-basic construction. This is another indication of the conservatism of the American steel industry.

A tabulation of American furnaces in 1958 shows 730 silica roofs still in operation. These furnaces varied in size from 75 to 550 tons. In this tabulation, roof life is recorded; although it varies widely from 63 heats to more than 200 heats, the average life is about 125 heats for furnaces up to 175 tons and only 80 heats for furnaces of 250 tons capacity and over. On the other hand, the all-basic roof has shown a life varying from 150 heats on 500-ton furnaces to over 500 heats on furnaces smaller than 200 tons. The variation in roof life depends upon the rate of firing the furnace and the use of oxygen. Thus, it seems apparent at the present time that an all-basic roof costs two to three times as much as a silica roof and lasts three to four times as long. Apparently, in the long run, the all-basic roof is cheaper than the silica roof.

Both the oxygen-blown converter and the oxygen-blown openhearth furnaces generate a large amount of dust and fume. The red color of the smoke leaving the openhearth furnaces shows which ones are using oxygen. In the oxygen-blown converter, fumes are collected in a

hood and passed into a dust cleaning system. These are either washing devices to cool and wash the gases, or more usually Cottrell precipitators. The amount of dust collected from an oxygen converter varies between 60 and 180 lb. per ton of steel produced. Plants which are located in or near cities have to install these costly dust cleaning units to meet the various city ordinances which regulate smoke control.

Oxygen Enrichment of Combustion Flame

If the oxygen in the combustion air is increased from 21% to 25 or 28% by adding oxygen, the flame temperature and characteristics in the openhearth furnace are changed. More fuel can be burned per hour, the volume of the furnace gases decreases and the temperature rises. In this practice, usually about 300 to 600 cu.ft. of oxygen is used per ton of steel melted. This oxygen enrichment is usually done during the preliminary stages of the heat when the furnace is cold, and the large amount of cold scrap charge is slow to come up to temperature. By increasing flame temperatures during this period, scrap can be melted at a much faster rate, and hot metal can be added much earlier. Usually, oxygen enrichment is stopped after the heat is melted. The U.S.S.R. and Germany have done much more along this line than the United States. It is stated that, if the maximum amount of oxygen in the flame is 600 cu.ft. per ton of steel, about 1 hr. in heat time is saved.

Oxygen in Electric Furnace Melting

Electric furnace charges are essentially all scrap. Rarely is much pig iron, which contains large amounts of carbon and other impurities, added. Since the high heat of the electric arc melts scrap very rapidly, the use of oxygen on every heat is not general practice. In one instance, a shop which melted high-carbon rail steel scrap used oxygen for about 1 hr. to reduce the carbon content of the melt. This is done by passing a consumable lance through a wicket hole in the door. Oxygen is used in electric furnaces in melting stainless steel heats. Since about one million tons of stainless steel are melted a year, the amount of oxygen used is considerable. In melting stainless steel scrap which contains large amounts of carbon, it is necessary to reduce the carbon content of the bath to about 0.03 or 0.05%. To accomplish this, a controlled period at the highest temperature is required to reduce the carbon content without much loss in chromium. The amount of oxygen consumed may be 300 to 600 cu.ft. per ton of steel, depending on desired carbon content.

Oxygen in the Blast Furnace

Blast furnaces blow a tremendous amount of wind, varying from 40,000 to 60,000 cu.ft. per min. To enrich such a blast by even a few percent would require an enormous amount of oxygen. If oxygen is added alone to the air, high hearth temperatures result. Faster melting rates then produce high-silicon irons. However, if steam and oxygen are added in about the same amount, hearth temperature can be regulated and a low-silicon iron can be produced. Emerick in his article cites experiments at Jones & Laughlin Steel Corp., where trial oxygen enrichment was varied from 0 to 2.5%. At the same time, the total moisture content of the blast was varied from 3 to 8 grains per cu.ft. With 1.5% enrichment and 5 grains of moisture per cu.ft., an increase in iron production resulted along with a small saving in coke consumption. When the air blast was increased to 23.5% oxygen with 7 grains of moisture per cu.ft., the iron production under these conditions was increased by 11.5% and the coke rate decreased 117 lb. per ton. There is certainly an attractive future for the addition of oxygen and steam to the blast.

It is evident that oxygen can accomplish spectacular increases in steel tonnages. The United States has been very laggard in promoting these applications while the Europeans have been aggressive and moved far ahead of us in the use of oxygen. There is a much greater percentage of all-basic openhearth furnaces in Germany and France, and the large production of converter steel using oxygen reflects their progress in this field. A recent article in *Iron and Coal Trades Review* in Great Britain takes the British steel industry to task for not developing the use of oxygen in their operations. Like the United States, most steel in England is made in basic openhearth furnaces, and openhearth operators have been much more backward in introducing oxygen practices in their plants.

There are no basic converters in the United States, mainly because our hot metal contains less than 0.50% P. However, there are instances where a basic-lined converter could be used with oxygen, and there may be some consideration of this old process in the United States. There will certainly be a number of new top-blown L-D converters installed in the United States, since these plants are making excellent steel at a lower cost than the present openhearth steel.

Steelmaking on the Move

Ultrasonic Vibrations Refine Grain Size

*By D. H. LANE, J. W. CUNNINGHAM and W. A. TILLER**

Vibration during consumable-electrode melting refines ingot grain structure and prevents segregation. Secret of the technique is low-loss transmission of sound energy through the bottom of the mold. Several 12-in. diameter ingots have been made in which ultrasonic energy was applied. (C5h, 1-74; Fe-b)

ADD ULTRASONIC VIBRATION to consumable-electrode melting, and improvement in ingot grain size and homogenization promises a big advance in metals technology. This technique is being developed at Westinghouse. The process, while still in an early stage, has lots of potential with existing alloys as well as those which are not now forgeable because of ingot faults. In the future it will probably be applied to air melting operations in addition to consumable-electrode vacuum arc melting.

Two defects are fairly common in ingots – columnar grain growth and grain-boundary segregation. They often cause trouble during forging. Planes of weakness occur where columnar grains growing in different directions meet and preferred orientation leads to anisotropy in forgings. To eliminate columnar grains and segregation in cast ingots, the molten metal has been vibrated, inoculated, or stirred. None of these attempts has been entirely successful; the ingot structure usually changed to an intermediate one which still contained columnar grains with limited equiaxed area.

Rugged Power Source Required

Ultrasonic vibration of a large mass such as an ingot demands a power source which can operate at high energy levels. We selected a magnetostrictive transducer made from stacked nickel laminations for preliminary work. It is rugged in design and can operate continuously at high power in converting electrical energy to sound energy. Best efficiency of our transducer was obtained in the frequency range of 5 to 60 kc.

Vibration of ingots during solidification has been tried before. Success was limited by the efficiency with which the vibrational energy can be transmitted to the ingot. In one technique, transducers are fastened to the walls and base of the mold. Much of the sound energy is dissipated at the mold-ingot interfaces as the cooling ingot shrinks from the mold walls. In another setup the mold functions as a transducer. This technique also proves inefficient because of poor mold-ingot contact and eddy-current losses at the mold and ingot surfaces. Both methods are successful in degassing liquid metals and in refining structures of small ingots; however, they do not effect similar improvements in large ingots.

In our method, the ultrasonic energy is transmitted to the ingot through a coupling bar which is brazed to the transducer and serves as the bot-

*Mr. Lane is an engineer in the materials engineering department, Mr. Cunningham is foreman of the metals processing laboratories, and Dr. Tiller is an advisory engineer at the Westinghouse Research Laboratories, Westinghouse Electric Corp., East Pittsburgh, Pa.

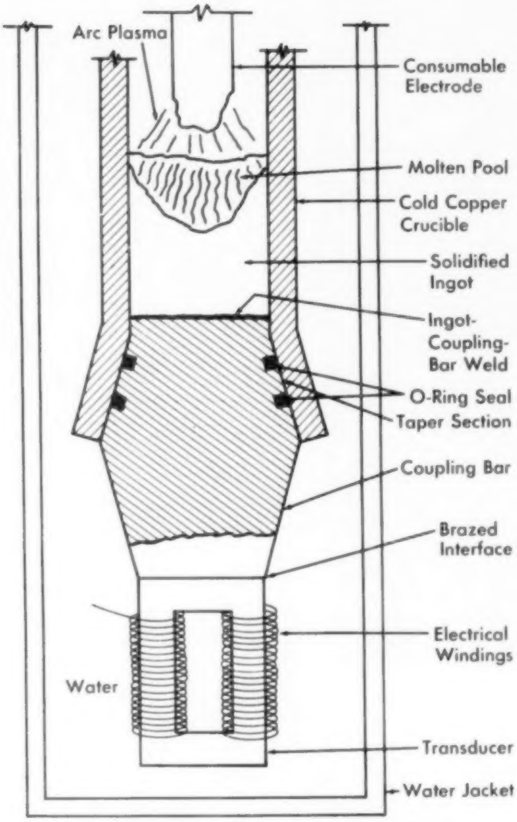


Fig. 1 – Apparatus for Consumable-Electrode Arc Melting With Ultrasonic Vibration. Transducer-coupling-bar assembly serves as the mold bottom

tom of the mold (Fig. 1). The ingot and bar are welded together at the start of the melting process. Thus a direct metallic path for the vibrational energy is provided from the transducer to the ingot. The efficiency of the technique is governed, however, by the area of the weld between the coupling bar and the ingot. Greater weld area means lower energy loss.

In early experiments, consumable electrodes of an austenitic, iron-base alloy (18 Mn, 5 Cr, 0.5 C) were arc melted in a 2½-in. diameter water cooled copper mold. A photograph of the transducer and coupling bar assembly used as the mold bottom is shown in Fig. 2. The transducer, a 5 × 2 × 2-in. stack of nickel laminations, was brazed to an iron coupling bar. Sound energy losses were minimized by isolating the transducer assembly from the mold with vacuum-seal O-rings.

Resonance Important

The initial arc was struck at very high current to melt a portion of the crucible base (the coupling bar). Amperage was then reduced to the lowest value which would produce a sound ingot, and the transducer was energized (400 w., 20 kc.). Adjusting the frequency to maintain maximum electrical power input to the transducer will maintain ingot vibration at a point near resonance, which is important for maximum efficiency. We measured the amplitude of the generated waves with a small piezo-electric transducer placed near the base of the trans-

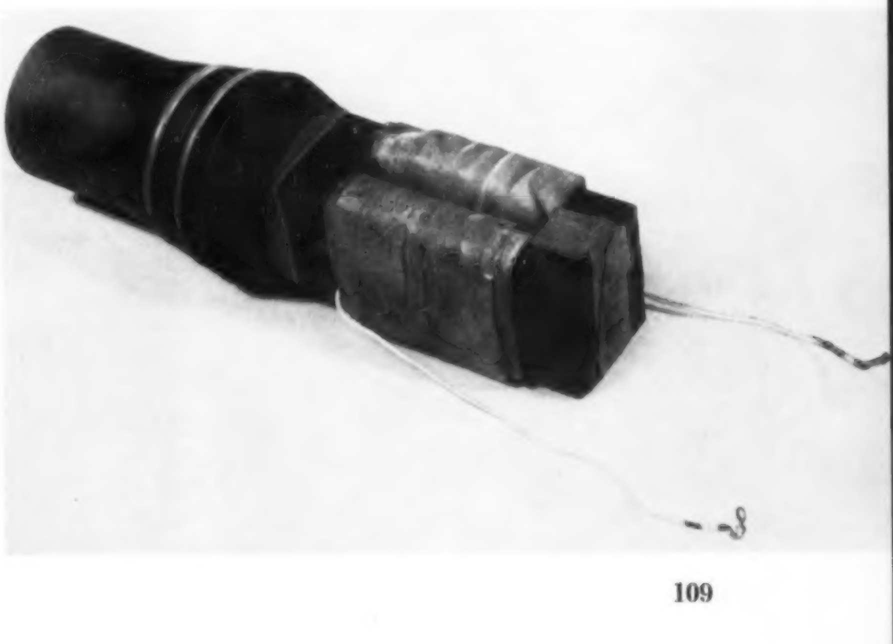


Fig. 2 – Transducer-Coupling-Bar Assembly. Transducer is made of stacked nickel laminations (0.008 in. thick) 5 × 2 × 2 in. O-rings on tapered section of coupling bar reduce energy losses to mold walls

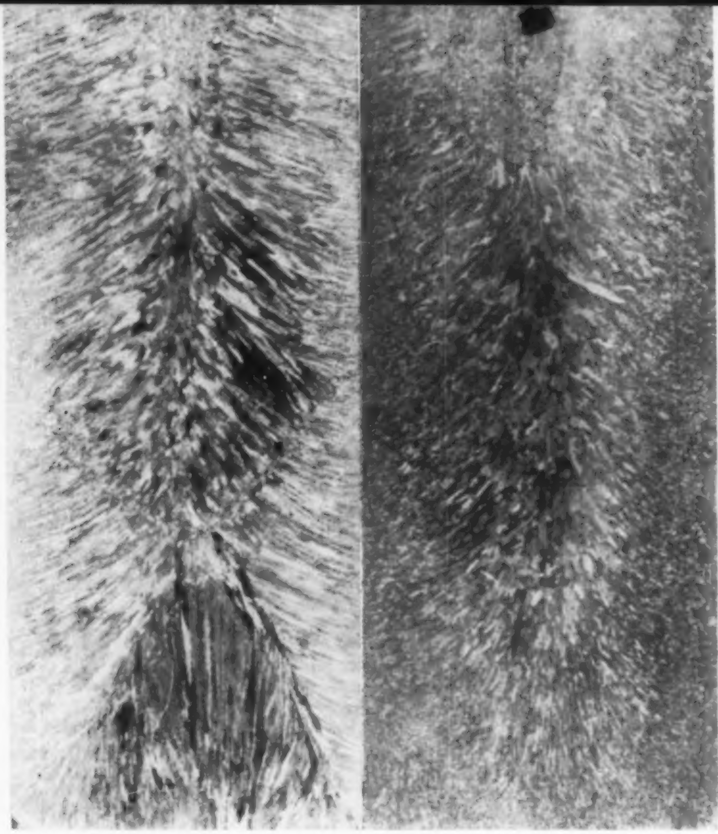


Fig. 3 – Macrostructures of an Austenitic Iron-Base Alloy Ingot, 2½ In. in Diameter, Made by Consumable-Electrode Vacuum-Arc Process. Left – Arc-cast ingot made without ultrasonic vibrations solidified as coarse structure of columnar grains. Right – Vibration has refined grain, reduced segregation, and eliminated planes of weakness in the ingot

ducer. The wave forms of the induced vibrations were then imposed on an oscilloscope and the frequency was varied to keep the amplitude of the wave at a maximum.

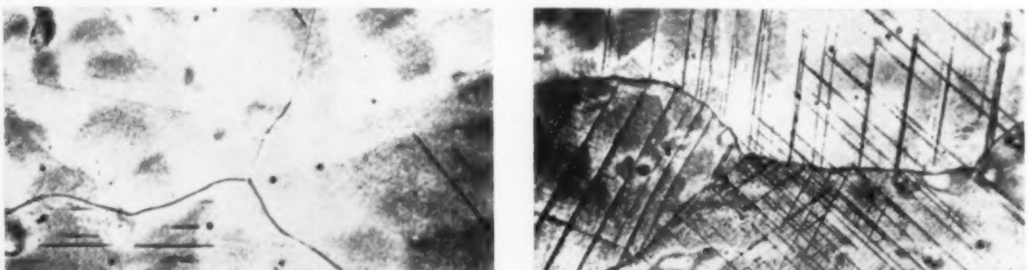
Ingot Structure Improved

Macro-etched sections of the two ingots – one standard, the other vibrated – are shown in Fig. 3. Ultrasonic vibrations have eliminated the prominent planes of weakness and have suppressed columnar grain growth.

Examination of etched microstructures of the two ingots revealed a series of line markings within the grains. Photomicrographs (Fig. 4) show that the lines are more prevalent in the vibrated ingot. Markings of this type are also observed in the same alloy after deformation and heat treatment. They are due to carbide precipitation on slip planes. In the vibrated ingot, the lines suggest that slip may be associated with the grain refinement which is attained.

The results of these experiments have been confirmed with other alloys of the same ingot size. More important – several 12-in. diameter ingots of other alloys have been arc cast by Westinghouse at its Blairsville, Pa., plant.

Fig. 4 – Photomicrographs of As-Cast Structures. Left – Control ingot (no vibration). Right – Carbide precipitation at slip planes is more extensive in vibrated ingot. Electrolytic polish, 250 ×



Vacuum Degassing in Ladle ... a New Technique in Steelmaking

Hydrogen and other gases are removed from molten steel while it is in the ladle. By purging with helium while the vacuum is being drawn, hydrogen is reduced to less than 2 ppm. in about 15 min. This new technique permits steel from one heat to be poured into several ingots. (D9m, 1-73)

A NEW AND DIFFERENT method for vacuum degassing has been successfully devised by A. Finkl & Sons Co., Chicago.* Surprisingly, considering its newness, the concept is about as simple as it can be. A ladle containing air-melted molten steel is merely lowered into a large chamber which is then closed and evacuated. After about 15 min., the ladle of degassed steel is removed from the chamber and poured.

Since it may seem strange that such a simple version of vacuum degassing has not been applied before, some history might be in order. Actually, some Europeans tried to degas steel in ladles several years ago, but results were poor and the project abandoned. According to Tix (reporting in *Electric Furnace Steel Conference Proceedings,* Vol. 13, 1955, p. 70), ". . . ladle degassing has only a limited range in application. Owing to the ferrostatic pressure of the contents of the ladle, . . ."†

However, these investigators used aluminum-killed steel and mechanical pumps. They also tapped the full slag into the ladle, a technique that Finkl engineers found very detrimental.

Another quesion that might arise is, "Why should a forging producer be interested in vacuum degassing?" Well, large die block forgings are a major item in Finkl's business. Being made of alloy steels, these die blocks are susceptible to ruptures when hydrogen is present. Like the producers of steel for large turbine rotors, Finkl became interested in vacuum degassing when results showed that the method could reduce hydrogen to levels at which rupturing from hydrogen flakes was no longer a problem.

They were offered several choices so far as technique was concerned. Aside from ladle degassing, there was available ladle-to-ladle degassing, and ladle-to-ingot degassing.

Since the company wanted to have equipment that could provide a wide variety of ingot sizes, they decided to try ladle degassing despite the adverse reports. They reasoned that, if the bugs could be worked out, the method would enable them to pour several different sizes of ingots from one heat.

*Some of the material in this article was presented by C. W. Finkl at the A.I.M.E. Electric Furnace Conference, Detroit, December 1958.

†What Mr. Tix means is that the steel on top weighs on the steel below to keep it from the vacuum. Thus, the steel at the bottom will not be completely degassed. Finkl overcomes this drawback by stirring the steel with helium injected under pressure at the bottom of the ladle.

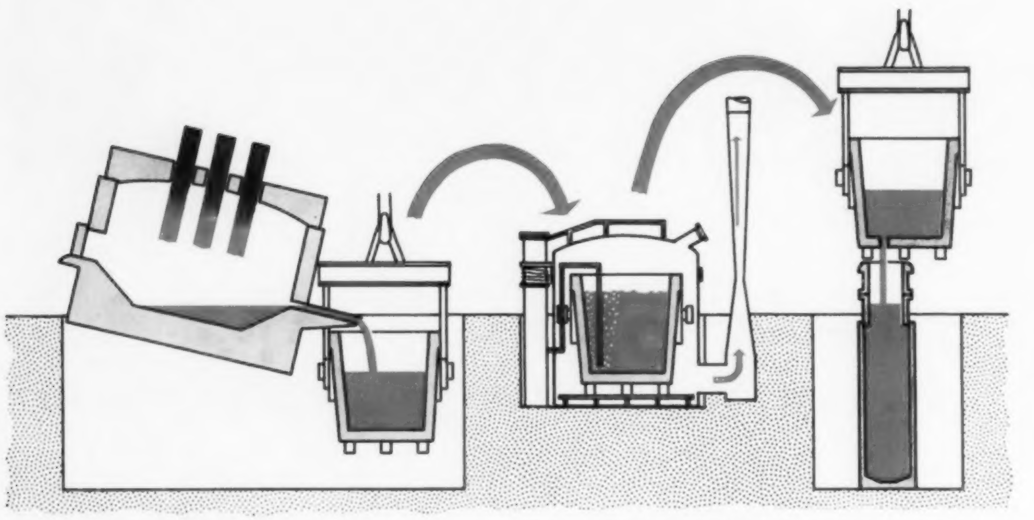


Fig. 1 – Diagram Showing Progress of Ladle From Electric Furnace to Degassing Tank to Pouring. A 35-ton heat can be degassed in about 15 min.

Equipment and Safety Precautions

A four-stage steam ejector was purchased that could pump 215 lb. per hr. of equivalent air at 500 microns or 0.5 mm. absolute pressure. This figures out to 71,165 cu.ft. per min. (cfm.) of air having a molecular weight of 29.* The ejectors were also designed to pump down 1000 cu.ft. to 500 microns in 5 min., the shortest possible tank evacuation time. (Speed is necessary because pumping can only be done while the ladle is in the tank, not before, as in stream degassing.) The first stage of the ejector was located as close to the tank as possible with the inlet of the first stage being bolted to the butterfly valve. This, in turn, is bolted to the outlet of the tank. The vacuum tank itself is 12 ft. 10 in. I.D. by 11 ft. 4 in. to the root of the dome. Total volume, including the circular segment of the dome, is 1592 cu.ft. This tank was planned to hold a 60-ton capacity ladle containing 37 tons of steel. (Finkl's heats average 35 tons.)

Steam for the ejectors is reduced from 135 to 100 psi. to insure constant pressure and quality. Cooling water is provided for the condensors from a cooling tower and 7000-gal. sump. It is interesting to note that when a cooling tower is used, enough steam is condensed to make up for the cooling tower's wind and evaporation losses. Hence no make-up water is required, but is provided anyway.

*This unit will also handle 385 lb. of equivalent air per hour at 1.22 mm., which is less than 70,000 cu.ft. of air per min. This shows how difficult it is to rate these things in cfm. Since most calculations of gas removal are by weight, perhaps it would be a good thing if people working with vacuum metallurgy would rate their units in lb. per hr. so a quick comparison of units can be made.

The control panel, which is the heart of the system, is laid out pictorially to aid operation. Electric interlocks make certain that ejectors can only be turned on in the proper sequence, and remain on only when the required steam, cooling water, control air, and electrical power are available. If the steam or water should fail or the third and fourth stages are turned off, the unit shuts down automatically. Shutdown is also controlled by a large red button on the control panel. If something should go wrong, this button completely shuts down the unit without further thought. A remote control station, adjacent to the vacuum tank, allows the operator to watch the boil through the window of the tank, while he operates the first and second stages of the steam ejector. He can shut down the unit and operate the device for removing the cover from the tank.

How the Unit Operates

The steel is made by the familiar double-slag practice with some exceptions. To control grain size, vanadium is used rather than aluminum. (Aluminum reduces the carbon monoxide boil while under vacuum.) About 30 to 40° F. of superheat is put into the bath prior to slag-off of the second slag. A second slag-off is needed since slag attacks refractory while under vacuum. Furthermore, the mass of slag on the bath reduces the boil, increases pump-down time, inhibits degassing, and gets the vacuum tank, ladle and first stage very dirty. The superheat and second slag-off take about 25 min. more furnace

Fig. 2 — Degassed Steel Lying Quietly in Ladle. During degassing, the steel is purged by helium injected at the bottom through a pipe which serves as the stopper rod. The gas increases turbulence so that more steel is brought to the surface to be degassed

Fig. 3 — Steel Pouring From Ladle Into Mold. Note that stream is compact and does not spark; this indicates that very little gas is present

Table I – Mid-Radius Tests of Heat Treated Blooms

	X-1573	X-1607*	X-1612*	X-1618
Tensile strength	167,000 psi.	168,500 psi.	166,000 psi.	164,000 psi.
Yield strength	141,600	145,200	141,200	140,000
Elongation	10%	15.0%	15.8%	11.5%
Reduction in area	19.2	41.8	42.6	26.1
Hydrogen	3.5 ppm.	1.7 ppm.	1.6 ppm.	2.9 ppm.
Oxygen	66	42	34	68

*Degassed heats.

time. An additional two points of carbon and manganese are added to make up for a like amount that is lost under vacuum. Tapping is normal with ferrosilicon added to the furnace. Calcium-silicon and carbon are added to the ladle if needed. Transfer to the vacuum tank is as quick as possible. As soon as the ladle is in the tank, the cover is closed and pump-down is started. While the vacuum is being drawn, helium, under pressure, is forced into the bath through a pipe which serves as the stopper rod. This thoroughly stirs the molten steel. Since the purging tube is protected by the stopper rod refractory, it will not melt through. After 15 min. total tank time, the ladle is removed and poured. Figure 1 illustrates the process.

Temperature drop is critical since time and temperature control is partially responsible for the success of this process. Immersion thermocouple readings reveal 60° F. drop from the furnace before tap to the ladle. Immediately after tap, with very little slag on the ladle, temperature drops 3 to 7° per min., depending on the amount of slag and condition of the ladle during degassing and teeming.

The layman can readily see if a poured heat has been degassed or not. As Fig. 3 shows, a degassed heat, regardless of final gas analysis, has a very tight, compact stream, with no sparking. It looks like a solid red hot bar. Fluidity is definitely increased. Through a given nozzle, a degassed heat can be poured about 30 to 40° F. cooler in the same length of time as an undegassed heat. Current average total time from tap to pour is now slightly less than 30 min. This figure is being consistently reduced. The operators feel that if it can be lowered to 25 min. no superheat will be required. This will save 15 min. furnace time. No additional labor is required by this process. With proper planning, workers have consistently, day after day, degassed every heat made.

Though ladle life has shortened about 20%, furnace life is relatively unchanged, in spite of the superheat. As for maintenance, every day the inside of the tank and the outside of the ladles are cleaned. Several hundred pounds of dirt come out of the first stage of the ejector every month. Other than this, the only maintenance is preventive.

What Has Been Accomplished

Though most of the vacuum heats were run on Finkl FX (a chromium-nickel-molybdenum die block steel), all steels containing nickel are degassed by this process. To quote averages, in the last 100 heats hydrogen has been reduced from 4.3 to 1.75 ppm., and oxygen from 86 to 44.6 ppm. Tests on several degassed FX heats proved that flakes had been eliminated. Ingots were forged to 14 in. square by about 8 ft. long and laid on the floor of the forge shop to cool. After they were cool enough to be transported, they were taken to the inspection department for daily sonic readings. After five to seven months, no flakes have been found.

In other tests, four large blooms of FX steel were forged from 40-in. ingots. Two blooms were from degassed heats; the others came from two heats that were not degassed. After forging, these blooms were isothermally annealed, austenitized, water quenched, and tempered for 20 hr. at 1070° F.

The average of two mid-radius tests from each heat treated bloom is shown in Table I. Average increases of 43% and 86% were obtained for the elongation and reduction in area after degassing, while the tensile and yield strengths varied less than 4%.

To sum up, Finkl's new degassing method provides a serviceable product which is low in hydrogen and other gases. So far, they have not altered their cooling practices to take advantage of the lower tendency toward rupturing, but this project is definitely planned for the near future.

A Report From the U.S.S.R.

Radio-Isotopes and Soviet Steel

*By ARTHUR B. TESMEN**

The Russians have evolved many methods for studying steelmaking processes with radio-isotopes. Blast furnace techniques which have been devised include ways to measure stock feeds, wear on furnace bottoms and charge levels. In the refining process, much work has been done on dephosphorization, desulphurization, scrap melting, and slag formation. Several experimental techniques are described. (D-general, 1-59)

Isotopes have been widely used in Russian metallurgy since about 1951. Figures of the U.S.S.R. Academy of Sciences show yearly savings of 1.5 billion rubles† in iron and steelmaking alone. In addition, isotopes have been extremely useful in solving many difficult metallurgical problems. More than 30 research institutes, 20 iron and steel mills, and a large number of metalworking plants are using this tool. Several national conferences have been held, and more than 200 papers published on their use in metallurgical research, process regulation, and quality control in ferrous and nonferrous production, melting, casting and fabricating. This article will summarize Soviet uses of this method, and give typical applications in the metals field.

What Is a Radio-Isotope?

A radio-isotope is an unstable version of an element. Identical to the stable isotope in atomic structure, it has a different atomic weight, and emits radiation – α and β particles and gamma rays – as it disintegrates. Radio-isotopes are used either as radiation sources or as tracers. Sources may be stationary (such as in radiographic flaw detection, thickness gaging of rolled sheet, strip and coatings, liquid level gaging and density measurements) or movable (to locate or follow a marked object, such as in liquid flow through piping, or radiographic quality control of a movable object).

Used as tracers, they emit specific identifying radiations while their chemical behavior is identical with that of their stable version. Materials "tagged" with the radioactive tracer atoms can be followed through complex processes and reactions. As such, they are used to study movements of material in systems which undergo complex physical and chemical changes. Some examples follow.

Blast Furnace Investigations

Investigating the blast furnace process with radioactive isotopes started at Novo-Tula Experimental Metallurgical Plant in 1951, and has been continued at Kuznetsk and Magnitogorsk

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†It is difficult to compare dollars with rubles. However, the official exchange rates are: foreign, 4 rubles to $1; tourist, 10 rubles to $1.

Metallurgical Combines, Dzerzhinsky, Azovstal, Stalinsk, Ilyich, and several other pig iron producing plants.

In studying movement of burden materials, radio-isotopes are introduced into a granule of ore, coke or lime. The tagged granule is then traced through the furnace by radiation counters strategically placed along the furnace shell, or by radioactivity measurements of pig iron or slag samples. At Novo-Tulsk P^{32} radio-isotope (as Fe_3P) and Fe^{59} (as an oxide) were added to the sinter before agglomeration. Baked sinter mass was broken into 2 to 3-in. pieces, and added to the furnace charge. Coke lumps were tagged with Fe^{59} and Ce^{141} isotopes by saturating in salts of these elements. An alternative method irradiates burden components in a nuclear reactor. This method is promising for tagging the ore particles, since it is difficult to tag the ore without affecting its mechanical properties.

Movement of the blast furnace materials is determined by two methods. In one scheme, the total time cycle – from charging of the stock into the top cone to its arrival at the smelting area and solution in the molten iron – can be measured. Tracer materials are introduced at the stock line at a definite interval before the iron is tapped, and the time cycle determined from the radioactivity measurements of the iron. This method does not require placement of radiation detectors and other special equipment, but it does not provide information on local rates of descent.

A more advanced method measures the rates of descent at eight furnace locations. Radioactive granules are introduced at the stock line, at a definite distance from the furnace centerline. To measure radiation, counters are placed at six furnace levels and two tuyeres.

As tagged ore, coke and lime travel through the furnace, their radioactivity is gradually registered at each level. Rate of travel is determined by measuring the time intervals between the maximum radiation intensities registered for each level, or by intensity increases from one level to another.

Radiation detectors can be placed outside of the shaft shell in the furnace lining or inside the furnace. The first version provides longest life and accessibility, but passage of radiation through the furnace lining greatly weakens its intensity. Granule radioactivity must be about 400 millicuries to increase the sensitivity of the measurements. Placement of radiation detectors in the furnace lining does not require openings in the furnace walls (with the attendant maintenance problems), and produces good results with tracers of about 1 to 10-millicurie intensity. In the the third version, detector probes are introduced into the furnace for 5 to 20 min., and tracer intensity requirements are lower than in the preceding method.

In a study conducted at the Dzerzhinsky Iron and Steel Works, tagged granules simulating ore were introduced into the top cone of the furnace 4 in. from the wall. It was found that the ore and the coke first shift over to the furnace centerline and then move over to the furnace periphery as they move down. Sinter travel was faster at the center than at the edge. Lime moves more slowly in the lower part of the stack than at the top, and faster at the periphery bottom than at the center, but still overtakes the coke in its downward movement 10 to 30 min. after its descent from the stockline.

Similar experiments at the Azovstal Works determined that coke moves more slowly than the ore and sinter, and the sinter moves faster in the center of the furnace than near the walls. Novo-Tulsk investigations showed that the slow-moving ringlike area in the lower part of the shaft and in the bosh decreases the effective furnace volume by 10 to 15%.

Isotopes have been used to study mixing and movement of molten materials in the hearth of the furnace in an attempt to improve pig iron quality. They are introduced into the liquid pig and slag in the furnace hearth, through the furnace tuyeres, or by placement in the bottom brickwork. Radioactivity measurements of the slag and iron samples indicate the nature and rates of mixing of the molten materials in the furnace hearth.

Control of Brickwork Wear

A method for studying and controlling furnace bottom wear is shown in Fig. 1. It is intended to signal excessive brickwork wear, prevent breakdowns, and time furnace repairs. A 30-millicurie radiation source (1) is placed into the lower layer of brick in an ampule; a detector is placed into the water cooled tube (2); 0.5-millicurie radiation sources are placed at (3); and other detectors (4) are located in the water cooled probes connected to the controllers and recorders at a common pulpit. Changes in the radiation intensity reported by the detectors signal the destruction of the brickwork area under control.

This study determined that round furnace hearths which were water cooled at the bottom

periphery have longest life, and truncated cone-shaped hearths have the shortest life. It is expected that isotope control will be incorporated into the newly built furnace, and into the existing equipment whenever an opportunity is presented for alterations and repair.

The movement of gases in the stack was investigated by introducing radon, a radioactive inert gas, through the tuyeres with a special explosive device, and measuring the radioactivity of the waste gases. Gas velocity through a 45,000-cu.ft. furnace was determined to be 73 ft. per sec.

A device for controlling the fill level is being tested at one of the largest Soviet iron works. First, 200-millicurie Co^{60} sources are placed at the maximum charge level. The counters, wired to the control booth, are placed at four locations. Whenever the charge level falls below any of the radiation counters, it records the increased intensity, and a signal lamp lights up at the control pulpit. According to engineers of the Dzerzhinsky Works (where such a device has been in operation since May 1958), it equalizes the rate of material travel and effects more uniform furnace operation.

The same mill has also developed an automatic measuring device for density of sintered coke. Radiation from the source passes through a coke layer in a weighing funnel and is measured by a detector connected with a continuous recorder. Maximum radiation absorption indicated increased coke losses with the slag; as much as 11 to 13 tons of coke was lost through the slag notches. Since the coke in the hearth is about 2400 to 2600° F., considerable heat is lost from the furnace. Designers of this device expect to increase furnace production and decrease coke consumption by automatic compensation for coke and sinter density variations.

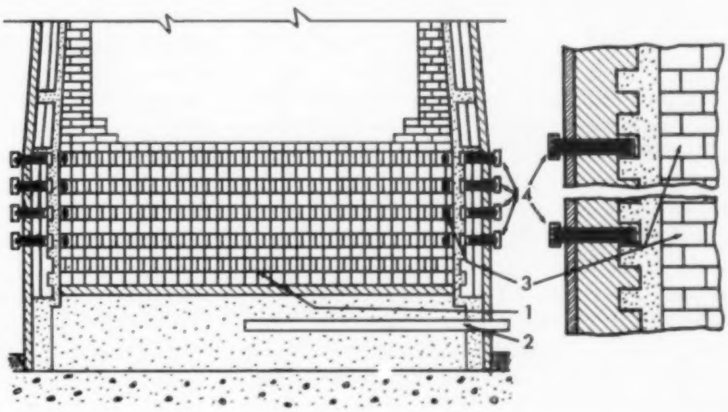


Fig. 1 – Investigating and Controlling Wear in a Blast Furnace Bottom. Points 1 and 3 show the location of radiation sources, and 2 and 4 indicate the sites of detectors

Isotopes Aid Steelmaking Research

While Winkler and Chipman at Massachusetts Institute of Technology were the first to use P^{32} to study dephosphorization equilibria, Soviet researchers have been using radioactive isotopes to investigate dephosphorization and desulphurization, scrap melting, slag formation, and formation of impurities in openhearth and electric furnace steelmaking. By tagging the phosphorus and sulphur-containing ingredients with the P^{32} and S^{35} isotopes, distribution of these elements between the iron and slag and their transition and solution heat effects were determined. Tests made with Fe^{59} and S^{35} isotopes established that the transfer of sulphur between metal and slag is accompanied by flow of iron into the slag, and that it is essentially a diffusion process. Sulphur transfer is slowest in the slag; transfer of iron occurs through the slag-metal interface at faster rates.

Basic openhearth furnaces at the Azovstal Works in the south of Russia refine high-phosphorus raw material into steel and high-phosphorus slags. The latter are used as soil conditioners. A method of using residual slag from the previous heat to aid dephosphorization was evaluated by tracer studies. An ampule containing a 25-millicurie mixture of radioactive P^{32} and iron powder was placed into the slag blanket. The isotope distributes itself through the slag, and part of it enters the metal, the amount being proportional to the slag-metal distribution coefficient of phosphorus. Radioactivity measurements of the slag samples (taken at intervals throughout the heat cycle, and correlated with

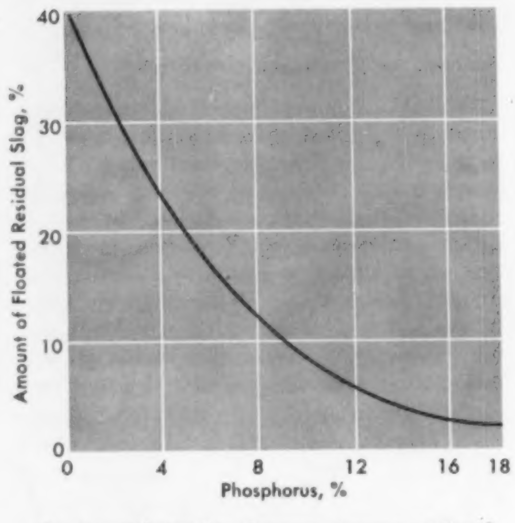


Fig. 2 – Relationship Between Amount of Residual Slag Floated During First Quarter of Melting and Phosphorus Content at End of Meltdown

the phosphorus content of refined steel) determined the amounts of residual slag which floated to the metal bath surface during the meltdown period. The results are shown in Fig. 2.

Scrap melting rate was determined by introducing iron or cobalt isotopes into the last ladle of liquid pig iron added to the furnace. Decreases in the radiation intensity of samples from the openhearth determined melting rate. The study indicated that melting rate rose with larger scrap surface, higher heat load and faster hot metal additions; it decreased as carbon oxidized.

The lime, ore and pig iron charging order was studied by tagging the lime with Ca^{45}, ore with P^{32}, and iron with Co^{60}. The dephosphorization rate was increased and the length of the meltdown period shortened by interspersing the lime layers with the ore, and by placing the lime deeper. In a 380-ton basic furnace, 70 to 80% of the scrap charge was dissolved in the liquid metal within 1 to 1½ hr. after the hot metal addition. Complete meltdown took 3 to 5 hr. more. A 45-lb. piece of ferrochromium placed in a 190-ton openhearth melted in 10 to 20 min.

Desulphurization of electric furnace transformer steel was "traced" by adding 150 millicuries of S^{35} to 1 ton of melt. Radioactivity measurements of the slag and metal samples (taken every 5 min.) indicated that intensive mixing of metal with the finishing slag and proper ferrosilicon additions aid desulphurization. However, the rate of pour into the ladle does not affect the distribution of sulphur in slag and metal. The Russians found that thorough desulphurization could be achieved with soda-ash and calcium-aluminum slags.

It is well known that the rapid formation of a slag of correct composition is important for the successful melting of steel. To determine the conditions of slag formation in an openhearth furnace, layers of lime, pig and ore were tagged with Ca, Fe, and P isotopes. The nature and rate of slag formation and the effects of ore-to-lime distributions in the charge were determined from radiation intensity measurements.

In studies of alloy additions, it was found that Co^{60} added through the middle door of a 350-ton furnace was evenly distributed through the metal bath within 10 to 20 min. When the isotope was added through the side door of the furnace, mixing took 10, 45 and 55 min. in 24, 50 and 350-ton furnaces. Tests of W^{185} showed that large amounts of this metal vaporize from the metal bath in the presence of basic slags.

A modification of the tracer method – isotope dilution – was also used to study slag formation. This method determines amounts too small to be measured by chemical or spectroscopic methods, or which cannot be quantitatively separated from other materials in a system. A carefully measured amount of isotope is introduced into the slag or liquid metal in a definite ratio to the amount of "stable" atoms of the same element present. After the isotope is uniformly distributed, the change in this ratio, as determined by radioactivity measurements, will establish the unknown amount of element originally present. The Azovstal Works uses this method to determine the effects of special slags, oxygen and briquetting of charge materials.

Contamination by Nonmetallic Inclusions

Production of steel with a minimum of nonmetallic inclusions depends largely upon the availability of data concerning the origin of these inclusions. Neither chemical analysis nor metallography can determine inclusion sources completely and accurately. Tagging the materials which come in contact with steel during its production makes it possible to trace each source of nonmetallic inclusions separately.

For example, Ca^{45} isotope (in the form of $CaCo_3$ and CaO) was placed into the refractory linings of the furnace, the ladle, and the pouring spout. Then, inclusions in steel ingots were electrolytically extracted and their source identified by radioactivity measurements. In a study

of contamination of ball bearing steels, 1.5 to 4.6% (depending on the type) of the inclusions were traced to the ladle lining and 0 to 0.7% to the lining of the pouring spout. Chamotte (36.4% $Al_2O_3 + TiO_2$), kaolin (44.4% $Al_2O_3 + TiO_2$), and clay (77.7% $Al_2O_3 + TiO_2$) contributed inclusions in descending order. While this work was based upon the use of Ca^{45}, isotopes of Al, Si, Mn and Mg are used for studies of inclusions originating from refractories, and during refining and deoxidization of steel.

Steel Pouring and Solidification

Solidification rates of rimmed and killed steels under various cooling conditions were studied by adding isotopes to the solidifying layers in the ingot mold. "Tagged" and "untagged" steel boundaries were detected later by contact radiography of templets cut from ingots. Relationships between the teeming rate, height of the ingot mold, and degree of solidification at various intervals after filling of the mold were established for ingots up to 6 tons.

Application of Ag^{110} isotope at the Chelyabinsk Pipe Works reduced the pilger-mill pipe reject rate from 44% to 15%. Rejections were due to laminations, blisters, eccentricity and blowholes. Since laminations and blisters were the principal defects, it was suspected that they resulted from nonmetallic inclusions collecting under the oxidized outer crust of the ingot to form a lap on the ingot surface. This produced laminations and blisters when the ingot was rolled into pipe.

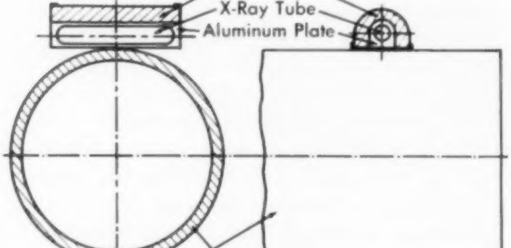


Fig. 3 – The X-Ray Tube as Used to Check Radioactivity of Pipe

To check this theory and trace the defect origin, Ag^{110} was added to powdered coke as $AgNO_3$, dried, and agglomerated into particles about 1 mm. in diameter (0.04 in.). The particles were added to the ingot crust immediately on its formation. Radioactivity of the ingot surface, the intermediate pierced product, and the finished pipe was measured by Geiger-Mueller detectors, by the method shown in Fig. 3. Laps with porosity and inclusion concentrations, laminations and blisters were indicated by intensity maximums, and the mechanism of their formation determined.

To eliminate these laps, tar-soaked wooden hoops were placed into ingot molds under the hot tops; this reduced the reject rate to 15%.

Isotopes in Casting

Isotopes Co^{60}, Ir^{192}, Ta^{182}, Cs^{134}, Fe^{59}, S^{35}, P^{32} and Ca^{45} have been used to control cupola melting, study refractory wear, determine the mechanism of graphite formation in nodular iron, study the nature of solidification in continuous casting, and ascertain the distribution of impurities and inclusions in the castings.

In a cupola operation, it is important to control the level of the charge, since a low level may cause air to be sucked in through the charge opening. This will chill cupola gases and reduce furnace efficiency. One method for level control uses a 25-millicurie Co^{60} source. It is located on the cupola shell at the desired control level, and is connected to the signaling counter. When the burden has reached the desired level, the radiation intensity will decrease sharply. When its level falls below the desired minimum, the intensity increase is automatically relayed to the feed mechanism which returns the furance load to the desired level.

Casting contamination caused by particles of the sand mold and core was studied with the Ca and P isotopes. Five millicuries of P^{32} (as H_3PO_4) was dissolved in water, neutralized, and mixed with the mold sand in a specified area. Since mold surfaces may wash into the casting (through impact of the metal stream, or rapid flow of molten metal, or crumbling due to the thermal gradient near the metal level), isotope tracers were placed to determine these effects, each separately. The casting was sectioned, and autoradiographs of each section then determined distribution of radioactive sand particles.

Rolling of Steel

As part of their drive toward automation, Soviet rolling mills have been adopting betagages to control thickness of steel sheet and strip. While the material travels between the radiation source and the detector, the amount of β-radiation that is absorbed gages the thick-

ness being measured. The instrument automatically compensates for changes in temperature, humidity, effect of dust particles, and other external factors.

Three types of gages have been designed. The first type uses Tl^{204} of 10 to 20 millicuries activity for gaging material in the 5 to 150-micron range; the second uses Ce^{144} (5 millicuries) or Sr^{90} for 50-micron to 1-mm. material; and the third uses Ir^{192} of 5 curies activity for sheet which is 2 to 10 mm. thick. Russian experience with the first two gages shows accuracies within $\pm$ 1.5% of the measured thickness; they claim accuracy of $\pm$ 50 microns for the third type of gage, provided the material is stationary.

The Russians are working on more rapid-acting and accurate gages to meet the demands of increased rolling speed and stricter tolerances, using scintillation counters with periodic correction during intervals between the measurements.

Continuous measurements of tin and zinc coatings are made with back reflection type gages, which use ionization chambers to measure Tl^{204} radiation back-scattered from the coating. Using 70 millicuries of this isotope assures accuracy of $\pm$ 0.15 micron for tin coatings and $\pm$ 2 microns for zinc coatings in the 0.002 to 1-mm. thickness range.

Metallurgical Research

Adding tracers to the melt, or bombarding it in a reactor (with subsequent measurements of radioactivity or autoradiographic techniques), makes it possible to determine the distribution of elements in a comparatively small area of an alloy. These methods have been extensively used by Soviet researchers to ascertain the manner in which elements are distributed in alloys. Other studies have determined atomic mobilities in solid solutions and the influence of alloying elements on the properties of alloys. The mobility of the solvent atoms is one of the main factors affecting structural changes in solid solutions, and their behavior under stress and at elevated temperatures. Addition of alloying elements leads to changes in atomic interactions, and hence in the properties of alloys.

Artificial radioactive isotopes were used to measure directly the diffusion coefficients of the alloy base elements. Calculation of the diffusion coefficient requires that the concentration change and the depth of the diffusion layer be measured at the same time. The work is precise, and radio-isotopes help by allowing minute concentrations of the diffusing substance to be determined. The substance to be investigated is mixed with the isotope and deposited on the specimen surface from which it penetrates into the layer underneath. Thin layers are then mechanically removed from the specimens and their intensities measured. Electropolishing to remove still thinner layers is even more accurate. The autoradiographic method is based on the effect of radiation upon a photographic emulsion. To obtain distribution of elements in an alloy, a thin section of an alloy containing a radioactive substance is prepared. Contact with the photographic plate emulsion then produces a mirror image (after development) of the radioactive distribution. The method is extremely sensitive. For example, enrichment of grain boundaries of Pb-Sb alloy by radioactive Pb was indicated when 1 atom of Pb isotope to 10^{10} atoms of stable Pb was present. Autoradiographic techniques have been used to study the distribution of elements and impurities in iron and nickel alloys; this work has indicated a marked chemical inhomogeneity within single phases and structural elements. Autoradiographs of several elements in a nickel alloy have indicated that elements such as molybdenum, columbium, zirconium and titanium and impurities such as tin, sulphur, phosphorus, antimony and cerium are present at the grain boundaries and in the interdendritic regions, while iron and tungsten are found within the grains.

Distribution study of tungsten in nickel showed that for 3.2% average content of tungsten in nickel, some regions are impoverished to 2.3% W and others enriched to 4.8% W. Nonuniform distribution of the alloying elements was observed within single grains and separate dendrites. Autoradiographs are also useful in determining concentrations of such impurities as sulphur, phosphorus, lead, tin and antimony at the grain boundaries of iron and nickel alloys.

In addition to these extensive uses in steel research, the Russians have used radio-isotopes in welding research. They have also determined behavior of liquid titanium in graphite crucibles to select correct thermal and time cycles for titanium melting, used Co^{60} to evaluate the homogeneity of the mechanical mixture of iron powders, and studied wear of motor parts and machine tools. While space is lacking to list all of the many uses that the Soviets have made of radioactive isotopes, this brief outline shows that they have made great advances. Their experience and ability in isotope use is fully comparable to ours.

Bigger, Better and Sounder Forgings—Part II

*By ERNEST E. THUM**

Service performance is simulated by a bored and notched 2-ft. disk spun to destruction. Tough steel should have transition temperature of 100° F. or lower, as judged by Charpy tests having 50% or more fibrous fracture. Vacuum casting of highly refined basic electric steel has greatly improved the soundness of forging ingots. (Q26s; AY, 4-51)

LAST MONTH was published the first part of a review of quite recent studies of large forgings, leading to the production of bigger and sounder rotors for large steam turbines and electric generators. Since the troubles with this class of heavy equipment arose, more has been learned about ultrasonic inspection, and its limitations have been much more sharply defined. Basic electric steel, vacuum cast, has also provided cleaner ingots with lower sulphur, phosphorus, oxygen and hydrogen, giving forgings of tougher steel, less liable to initiate cracks at the inevitable localized stress-raisers and to resist their propagation, once started.

This final section will describe the specialized tests devised to simulate the service performance of large rotating masses of metal, and the modifications in manufacturing practices which have resulted from the information gained thereby.

It was long assumed that stresses in an operating rotor can be simulated by spinning a disk made of the same material (Fig. 6†). Under this assumption the average bursting strength (ABS) would be the centrifugal stress L_c divided by the area on the diameter; that is

$$ABS = L_c \div A = L_c \div Dt$$

The old theory of design was that this should equal the ultimate tensile strength (UTS) of the metal as determined by the standard 0.505-in. test piece – that is, that ABS = UTS, and a factor of safety of four was commonly used by the designers.

This was a satisfactory concept until 1953 when certain rotors failed under working conditions such that the actual average bursting strength of the massive forging was one third to one quarter of the ultimate tensile strength! Furthermore, when the fragments were sampled, they proved to have the expected and specified tensile properties – normal tensile strength, elastic limit, reduction of area and elongation. The fly in the ointment here was that the fracture surfaces of the small test pieces were free from serious stress-raisers, while disastrous rotor breaks would start at some defect such as a flake, a machined notch or a group of inclusions.

Now, it is not enough to blame the obvious. For example, Pittsburg generator No. 1 split in two, the break starting from an accumulation of slag particles near the axis. Pittsburg generator No. 3, built to the same specifications at the same time and with substantially equivalent operational history, was removed intact for study and a similar accumulation of slag particles was trepanned from its axis. Rotor No. 1 broke and Rotor No. 2 didn't! Furthermore, when small disks like Fig. 6 from each of them were spun to destruction both gave the same result, namely ABS = UTS or ABS ÷ UTS = 1.00. Evidently

*Editor-in-Chief, *Metal Progress*. The observations contained herein – his own – were principally inspired by a visit with Dolph G. Ebeling, head of metallurgy, and other members of the technical staff of the Large Steam Turbine-Generator Department of the General Electric Co., Schenectady, N. Y. Supplementary ideas were gathered at the First National Metals Engineering Conference of the American Society of Mechanical Engineers, held in Albany, N. Y., April 29 to May 1, 1950.

†Figures are numbered consecutively from the previous installment.

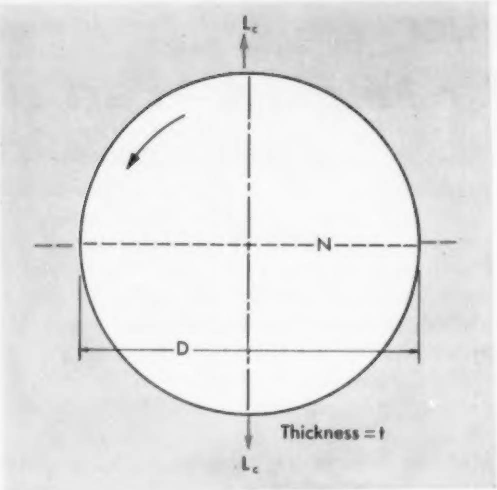


Fig. 6 – Sketch of Small Test Disk, Supposed to Simulate Action of Metal in Large Rotors When Spun Rapidly

some other means would have to be found to distinguish a safe rotor from a dangerous one.

This has been achieved by bringing in the criteria of size of the piece and the character of the fracture. In taking a look at the first one, size, the engineers at General Electric made a series of notched bars of various sizes which were broken in bending in a large testing machine. The bars were similar in shape to the standard Charpy V-notch impact specimen, but they ranged in size up to a 9 × 9-in. cross section. The notch depth was maintained at 20% of the gross depth and the notch radii were usually maintained constant at 0.005 in. Results of these tests indicated the influence of restraint at the base of the notch – the larger the test piece the smaller the chance of preliminary ductile flow in directions normal to the principal stress.

In some steels, the load-carrying capacities of these notched beams were seriously reduced as the size of the specimens was increased. This is shown in Fig. 7, where the nominal bending stress at the root of the notch is plotted against the width (and depth) of the specimens. The curves contrast the results on specimens cut from fragments of the "Arizona" rotor and from another forging of similar chemical composition. It will be noted that these tests were successful in reproducing the catastrophic fracture of steel from one of the defective rotors at very low stress levels, comparable with those that existed at the time of the rotor failure.

Character of Fracture – A notable difference between the steels which suffered a large loss in bending strength with increasing size and those which did not was in their ductile-to-brittle transition temperature as determined in the standardized Charpy impact test. It has long been known that the energy absorbed on impact test by any ferritic steel depends on the temperature of the test piece. The metal is "tough" at high temperature and "brittle" at low. Somewhere in between is a "transition" temperature – frequently located at where the Charpy test piece absorbs 15 ft-lb. of energy. The general situation is shown in the solid line of Fig. 8.

However, the men at Schenectady place much emphasis on the *appearance* of the fracture; the proportion of cleavage (transcrystalline) fracture in the break is noted and plotted and the remainder of the area is fibrous or intercrystalline. By

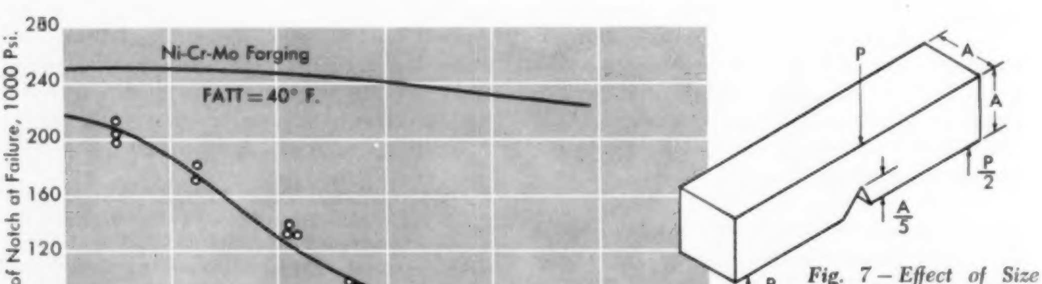
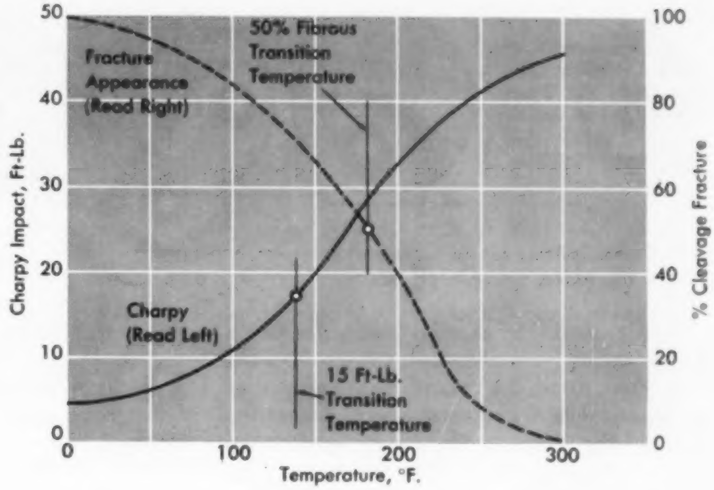


Fig. 7 – Effect of Size on Maximum Fiber Stress at Fracture of Notched Ni-Cr-Mo Bars Made From Broken "Arizona" Forging, and Test Bars From Another Large Forging of Much Lower Transition Temperature

Fig. 8 – *Influence of Temperature on Energy Absorption and Fracture Appearance of Ni-Mo-V Steel From Broken Pittsburg Rotor. The "Fracture Appearance Transition Temperature" (FATT) of this steel is about 175° F.*



this criterion the transition temperature is where the fracture is half fibrous and half cleavage. As also shown in Fig. 8, the metal in fragments from the Pittsburg No. 1 rotor had a fracture appearance transition temperature (FATT) of 175° F.

Disk Tests – Such experiments led the engineers at Schenectady to go one step further in their attempts to develop "model" tests that would provide reliable indications of steel performance in large rotating bodies. For this they turned to tests of spinning disks. Their first tests were conducted in a relatively small spin pit which could burst disks approximately 10 in. diameter and ½ in. thick. Some of these results are summarized in Fig. 9 and they show that the introduction of stress concentrations into spinning disks could lower the bursting strength and this is particularly dangerous if the steel were not ductile. The sketch summarizes results on "tough" metal – FATT 40° F. – and of "brittle" metal from burst rotors – FATT 275° or higher. Sensitivity (S) is appraised by dividing the average bursting stress of the disk by the tensile strength of a 0.505-in. tension specimen – that is, S = ABS ÷ TS. It is to be noted that a 4-in. center hole, simulating the axial bore in the rotor, does not change S for the ductile material even though such a hole is a stress-raiser, doubling the stress at its perimeter. Seemingly the ductile steel could deform plastically enough to prevent any crack from starting at such a place. The brittle metal could not; note that S = 0.78 if the disk was merely centerbored.

The third sketch shows more dangerous conditions when a center bore is supplemented by 45° notches 1 in. deep in the outer rim. S for ductile metal is then 0.87 and 0.57 for brittle. However, the investigators hit the jackpot when the notch was put into the *inner* bore – simulating the presence of axial bursts or inclusions not removed even by trepanning. S for the brittle material then comes out to be 0.29, right where the rotors actually broke in service – 0.25 to 0.33 of their tensile strength.

These results clearly demonstrated the effect of stress concentrations and the conditions of restraint on the fracture behavior of these rotating bodies. Clearly, it was important to extend these studies to thicker disks and cylinders in order to minimize the plastic flow that might take place in these relatively thin disks. For this purpose, the notch bursting tests are now performed in heavily armored pits. Normally the disks are tested at 70° F., but since it takes such a short time and the large disks change temperature slowly, tests can be made at any desired temperature merely by preheating or cooling the disks immediately before closing the test-rig. Another heated pit conducts long-time spin-rupture tests at elevated temperatures.

As regards the effects of geometric factors, it has been found that the bursting strength of thick disks is somewhat lower than thin disks, but above 3 in. thick there is little further reduction. Therefore, the Schenectady engineers have standardized on the following design for the spin-test piece: 24 in. O.D., 4 in. I.D., 3 in. thick, with two longitudinal internal notches in the bore 1 in. deep with a 0.005-in. root radius.

Results using this specimen are summarized in Fig. 10, which correlates ABS (corrected for variations in tensile fracture stress which is

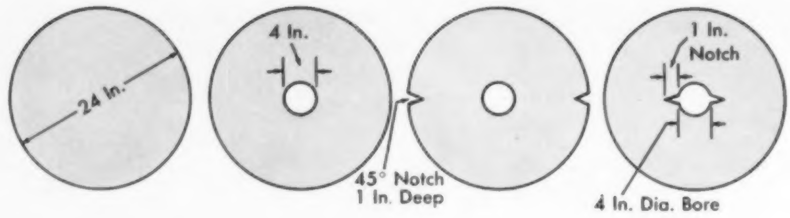


Fig. 9 – Results of Notch Bursting Tests on Disks Cut From Ductile and Brittle Rotor Steel and Notched Variously.

S*, Ductile, FATT = 40° F.	1.00	1.00	0.87	0.57
S*, Brittle, FATT = 275° F.	1.00	0.78	0.57	0.29

affected primarily by ductility) with the FATT as determined in a standard Charpy V-notch impact test. Both FATT and tensile properties are measured in a transverse direction near the center of the forging. This figure contains the experimental data for a wide variety of alloy compositions and heat treatments and it will be noted, first, that the correlation is quite good for all alloys, and second, that the FATT exerts a powerful effect on the bursting behavior of disks. With high transition temperatures, the bursting strengths are just in the range of those rotors that broke in service, whereas tougher materials will develop bursting strengths two or three times as great.

This extensive, and very expensive, testing program thus demonstrated that the cause of the rotor failures in service was the combination of some type of sharp stress concentration (flakes, machined notches, or inclusions) and a steel with a low capacity for plastic flow under conditions of high restraint.

A final verification of the reliability of this disk test, proving that it is the moderate-sized test which can be performed in the laboratory and which does represent actual service conditions, comes from work done on four rotors removed from service. For this puropse, the General Electric Co. has erected near the village of Malta an old and greatly reinforced armature casing made of welded and ribbed plate, within which sections of full-sized rotors can be spun to destruction. (This is really expensive business!) To date, four such retired rotors have been tested, and compared with tests on 24-in. disks cut from the rotors themselves.

Rotor A had a high fracture appearance transition temperature (FATT = 240° F.). It had originally been center bored and before test the center bore was notched end to end in the same way as the test disks. Small disks said it would burst at about 8% overspeed. It did.

Rotor B had a low FATT (80° F.). It also was internally notched, end to end. A test disk said it would burst at 50% overspeed. It was run 3 min. at 60% overspeed without trouble, during which the forging carried about 2.5 times the design stress.

*S = ratio of average tangential stress at fracture to tensile strength of unnotched 0.505-in. round bars.

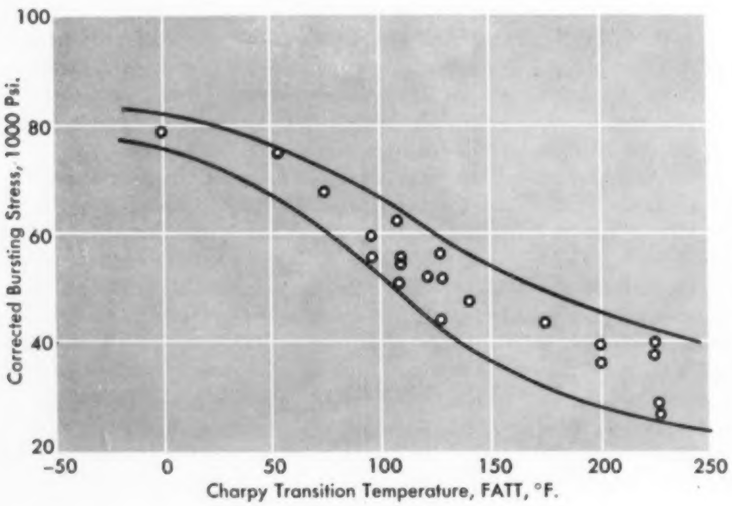


Fig. 10 – Corrected Bursting Stress of Large Forgings Versus Fracture Appearance Transition Temperature as Determined From Standard Charpy Specimens. Vertical ordinate is the observed average bursting stress × 140,000 ÷ true fractture strength (which is a function of the strength and reduction of area in the standard tensile test)

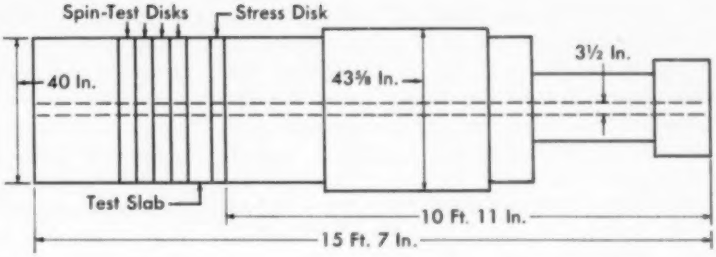


Fig. 11 – Outline Drawing of 25-Ton Rotor Forging With Prolongation for Test Disks and Other Specimens

Rotor C had a rather high FATT (200° F.). It had originally been bored and was not notched before testing. Disks said the danger point was 50% overspeed if no severe stress concentrations were present. None were observed in usual inspection and it safely withstood the proof test given to Rotor B.

Rotor D was solid (unbored) and had medium FATT (180° F.). It was tested as received. Disks again said the danger point was above 50% overspeed. It was run up to 56% overspeed safely and the test stopped.

Improvements in Forgings

Further correlation of low FATT with high bursting strength has been derived from experiments with more than 50 disks cut from 36 forgings delivered with extra material for tests (such as shown in Fig. 11), from old forgings rejected for various reasons, from the three rotors which broke in service, and from suspicious equipment recently withdrawn from operation. Cooperating in this program, steel plants have varied their steelmaking and forging methods as laboratory work indicates desirable modifications. One forging has been bought in England and three in Germany to investigate the properties of metal thought by foreign metallurgists to be optimum in composition and treatment. Periodic conferences are held with American steelmakers. Interchange of information among the electrical and steel industry is through a Task Group on Brittle Fracture* of the A.S.T.M.

Obviously such tests as indicated above are expensive so they must be carefully planned to give the maximum information. As noted above, Fig. 10 shows the relationship of bursting strength of bore-notched disks with their fracture appearance transition temperatures (FATT) as observed in a series of Charpy tests such as in Fig. 8. Other correlations show that FATT (Charpy) is apparently related to the transformation temperature; it is desirable that the austenite in these large forgings, which cannot be quench hardened to any depth, should transform on air cooling at their natural rate of about 100° F. per hr. into low-temperature bainite rather than high-temperature bainite. Furthermore, the austenitizing anneal in the forge plant should be at the lowest practicable temperature to prevent large grain growth and a coarsened structure in the final rotor. To achieve these desirable microstructures, much study has been given to the effects of small chromium additions to the conventional Ni-Mo-V rotor steels to increase their hardenability and still avoid that old bugbear, temper brittleness. Preliminary results are encouraging; improved alloys will be necessary before sizes and speeds of new rotating equipment can be increased.

One of the most important achievements, so far, has been a modification of the "standard" 0.30 C, 2.75 Ni, 0.5 Mo, 0.1 V analysis which has proved to be a pretty satisfactory compromise for the various requirements of the different parts of the machine, briefly stated:

For the high-pressure stage of the turbine – high-temperature strength and ductility, as well as dimensional stability (creep resistance) up to operating temperatures of 1000° F.

For the low-pressure stage where centrifugal stresses are high due to the long blades attached – high strength and toughness at 300° F.

For the intermediate stage, properties should be intermediate.

For the generator rotor, strength and toughness at moderate temperatures are needed and to this must be added good magnetic permeability. The latter requirement also indicates that the forging should not be center-bored.

To meet these requirements, the much-used Ni-Mo-V combination has good magnetic permeability, is free from temper embrittlement, is stable dimensionally and metallurgically under

*A. O. Schaefer, chairman, president Pencoyd Steel & Forge Corp., Philadelphia, and past-president American Society for Metals. This task group is also sponsoring an independent investigation of temper brittleness – the tendency of certain alloy steels to lose toughness if slowly cooled from desirable tempering temperatures.

the operating temperatures, and has small tendency toward segregation of alloy content in center or top of ingot. In recent forgings the molybdenum content has been lowered slightly so the final microstructure can contain some proeutectoid ferrite, a smaller grain size, and a much lower FATT.

This alloy does have some drawbacks: It has a high tendency to absorb hydrogen, but this has been corrected by vacuum pouring. It is not as strong as desired; said in another way, a preferred alloy should have a higher hardenability on slow cooling. Some important changes have been made in chemical analysis. As already indicated, steelmaking practice has gone over exclusively to basic electric furnaces, to drive sulphur and phosphorus down. Further, since glassy manganese silicate inclusions have been highly suspect in the operational failures, manganese has been reduced from the old 0.75 to 0.50%. As a consequence of these new practices, the sonic quality of forgings has been greatly improved in the last few years. Not only are the number of rotors rejected for sonic indications reduced to a vanishing point, but the average quality has been raised significantly.

One other disadvantage of the Ni-Mo-V steel may be mentioned: It can have a high transition temperature. In this respect it appears that composition and heat treatment are of more importance than minor variations in steelmaking and forging techniques; prime factors are lower temperature for transformation of austenite into bainite (achieved by reducing molybdenum to 0.30%) and a lower austenitizing temperature during the final heat treatment.

Toughness has been improved significantly. Old specifications said nothing about transition temperature (FATT), and in the Arizona rotor it was 275° F. Since 1957 it has been specified at 175° max. and it is intended to lower it still further to 140° F. The average for forgings received by G.E. during 1958 was 95° F.

Work in Progress

This does not mean that all problems are solved. All details of the design of turbo-alternators now on order or proposed have been scrutinized to eliminate sharp mechanical notches. The following projects are also receiving concentrated attention by the development and applied research groups at Schenectady:

Devise more accurate and quantitative methods for extracting and identifying the tiny nonmetallic inclusions, and formulate some method acceptable to both steelmaker and electrical manufacturer so steels can be rated as to microstructure and by inclusion counts.

Several types of inhomogeneity are of interest. One is the segregation of elements from top to bottom and from surface to center of these large ingots. Improvement in this respect would decrease bottom and top discards and raise the yield, forging to ingot – now 40% or less. Another problem is the localized banding or pencil-shaped segregation streaks having different hardness and ductility from the surrounding metal. Such streaks of alloy-rich metal surround networks of sulphides or other inclusions. Whenever the apex of a notch in a test disk falls in such a streak, the fracture strength is low, and this causes most of the scatter in the data.

In cooperation with the suppliers of the forgings, the Schenectady men are making an extensive mathematical and physical study of the ingot solidification process to determine the mold and casting variables which must be controlled to improve uniformity and eliminate the last vestiges of pipe.

Another important study is of temper embrittlement, a characteristic of higher alloy steels of deeper hardenability. For example, 2.5 Ni, 1.3 Cr, 0.5 Mo, 0.1 V has a much lower FATT than the "standard" Ni-Mo-V when quenched in small pieces from tempering temperatures, and is stronger – but these advantages fade when a large forging cools slowly (as it must). As noted above, the A.S.T.M.'s committee is also concentrating on this mystery. Minor variations in composition seem to have a disproportionately large influence on temper embrittlement; perhaps the nigger in the woodpile is minute amounts of tramp elements, not analyzed for but doubtless existing. Minor variations in steel manufacturing may also exercise considerable influence.

Finally to be mentioned is a study of variations in the chemical analyses and processing. Extensive data on about 500 forgings have been collected. It requires seven I.B.M. punch cards to contain all the encoded results from each. It was recently desired to step up considerably the physical requirements for forgings for two machines on order. The punch cards were fed through the computing machine to find the optimum combination of composition, treatment and magnetic and mechanical properties. Three forgings (one spare) were ordered to such a specification. They met the requirements with exceptionally good properties!

Short Runs

"Across-the-Line" Operation of Silicon Carbide Heating Elements

By W. E. MACER*

SILICON CARBIDE HEATING ELEMENTS can be connected "across-the-line" without transformers for economical metal processing up to 2000° F. They provide simplicity and versatility for heat treating and can be easily and quickly replaced without complete shutdown.

Elements vary in size from 4 in. long × 1/4 in. diameter to over 8 ft. long × 2 1/8 in. diameter. They are made of self-bonded silicon carbide, material once used almost exclusively for grinding wheels, coated abrasives, and refractories.

The center or heating section of the elements has a resistance of approximately 0.1 ohm per cc. The terminal ends have much lower resistance. Thus, the heat developed in the terminal ends is only a small portion of the total input. Extremities of the terminals are metallized with aluminum to provide low contact resistance.

Elements are strong in compression but low in tensile strength and susceptible to damage from vibration and mechanical shock. However, either vertical or horizontal mounting is possible. In a typical horizontal installation, holes slightly larger than the diameter of the element are drilled through the furnace walls. The terminal portions of the elements are then laid flat in the bottom of these holes so that the heating section spans the furnace chamber and the wall supports the elements. In vertical installations, heating rods are on adjustable mounting brackets.

Elements may be connected in parallel, series, or combinations of the two but only those which are matched should be connected in series. A new element should never be connected in series with a used one.

The input to heating elements connected "across-the-line" is controlled by the on-off method using an automatic pyrometer and magnetic contactor. Switches in the contactor coil circuit permit selected pairs or groups of elements to remain on at all times and others to be on-off controlled by the pyrometer.

*Refractories Div., Carborundum Co., Niagara Falls, N. Y.

Fig. 1 – Resistance-Temperature Characteristics of Silicon Carbide Heating Elements (Globar Delta)

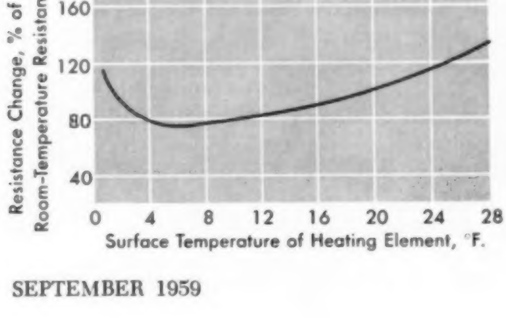
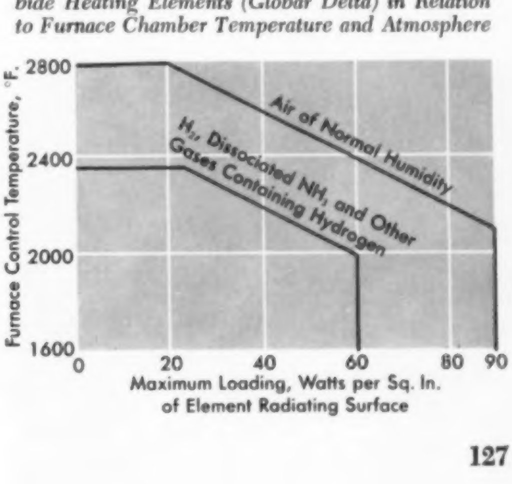


Fig. 2 – Maximum Watt Loading of Silicon Carbide Heating Elements (Globar Delta) in Relation to Furnace Chamber Temperature and Atmosphere



Resistance of the element varies with surface temperature. When a furnace is turned on, the resistance drops until the surface temperature of the element reaches about 800° F. in 2 to 5 min., then rises, as shown in Fig. 1.

All silicon carbide heating elements increase in resistance with use. Hence, when designing a furnace in which the rods will be operated directly off a 115 or 230-v. line or any fixed voltage, the rate of increase in resistance must be considered. Usually 25 to 50% overpower should be provided. If enough elements are installed so that the initial input to the furnace at operating temperature with new elements is 50% more than is required, it will be possible to obtain service from the elements until their resistance has increased 50%. Unless the elements can be reconnected, this would be the length of time they might be operated with on-off control at the original applied voltage.

Silicon carbide rods are more refractory than most metallic heating elements and can be operated at higher specific watt loadings and temperatures. Figure 2 shows the maximum power (watts per sq.in. of radiating surface) for operation at various temperatures and in different atmospheres.

Interest in electric furnaces which are equipped with silicon carbide elements is increasing. Across-the-line operation makes them more versatile. Long life, ease of replacement and maintenance, and low initial cost are attractive features to metals processors. The Sentry Co., Foxboro, Mass., for example, uses silicon carbide elements across-the-line exclusively in their metallurgical furnaces. Three of them are used by the Grobet File Co., Inc., to heat treat rotary and chisel-cut files. Heat treatment is particularly critical here because the cutting edges and flutes of the files are formed by impact and must be protected during hardening. Hamilton Watch Co. uses two furnaces for experimental work on high speed steel alloys, and for production heat treating of miniature form cutters, reamers, and small drills.

The Electric Wire Co., North Hampton, Mass., has two furnaces in operation which use 32 silicon carbide elements across a 220-v. line. The firm produces small-diameter wire drawn from about 42 alloys including nickel, Monel, Inconel and stainless steel.

The first furnace, built approximately 18 months ago, still uses the original elements. They operate continuously between 2000 and 2250° F., occasionally at 1800° F.

Wire passes through the furnaces in Inconel tubes containing cracked ammonia. Production of stainless steel wire is approximately 6000 lb. daily. After 18 months' service, the increase in resistance of the elements has been negligible.

Beryllium Heat Shield Forged by Heavy Press

Brush Beryllium Co. and Alcoa have combined their operations to produce a heat-absorbing shield for the nation's first manned spaceship. To produce this shield ("heat sink" in space slang), Brush first hot pressed a beryllium billet, 62 in. in diameter. A special process – involving simultaneous application of vacuum, heat and pressure to beryllium powder – did the job. After preliminary machining, the billet was encased in steel and shipped to Alcoa's Cleveland works for forging. There, the billet was first heated to about 2000° F. A huge manipulator then removed the steel-jacketed piece of beryllium, and placed it on a preheated die. Following this, Alcoa's 50,000-ton press, one of the largest in the country, squeezed the beryllium billet into the saucer-shaped disk, 80 in. across and 3 in. thick, shown in the photograph.

The forged part will be returned to Brush for precision machining. When the final operation – ultrasonic inspection by Alcoa – is completed, McDonnell Aircraft Corp. will receive the finished piece to install in N.A.S.A.'s Project Mercury capsule.

Fig. 1 – This Saucer-Shaped Beryllium Disk Is Being Removed From Alcoa's 50,000-Ton Press After Forging. Aluminized suits protect the workers from the heat

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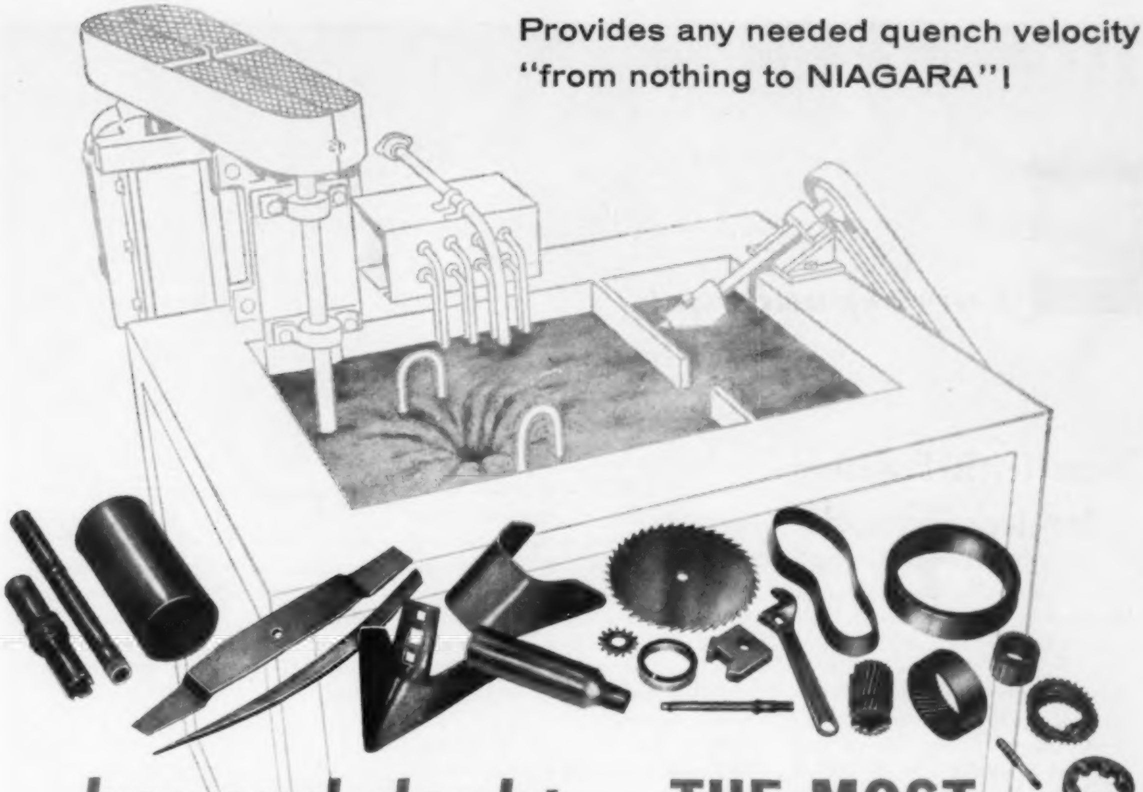

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Correspondence

Impact Test for Evaluating Toolsteels Discussed

BETHLEHEM, PA.

In "Impact Test for Evaluating Toolsteels", by Gary Steven, which appeared in the May 1959 issue of *Metal Progress*, p. 76, the author has accurately described the difficulties involved in impact testing of toolsteels. An even more difficult task – that of indicating how the impact values can be used – has not been attacked. In fact, this second task does not appear to have been recognized as a problem since the author says, in the closing paragraph: "As is evident, this new test is useful in comparing different toolsteel classes ... The optimum heat treatment for a given grade of toolsteel can easily be established."

In my opinion it is not evident that this new impact test, or any impact test yet devised, is useful in comparing different toolsteel classes. Further, it will be difficult, if not impossible, to establish the optimum heat treatment for a given grade of toolsteel using impact test results.

The data shown in Table II of the article, comparing different toolsteel classes, can lead to serious misapplications of grades of steel. For example, cold header dies made of W 1 carbon toolsteel often fail in service in a brittle manner. Since the impact strength of D-2 high-carbon high-chromium toolsteel is shown as better than that of W 1 steel, it might be assumed that D-2 steel would be better than W 1 steel for this purpose. Experience proves that this is not so.

With respect to the observation that M-2 high speed steel shows higher impact strength after 600° F. temper than conventional tempers at 1000 to 1050° F., it should be noted that many different types of impact tests have indicated the same thing in the past. However, cutting tools heat treated with tempers below 1000° F. have shown two serious deficiencies in service:

1. The tools do not cut efficiently.
2. The tools fail prematurely in a brittle manner.

Thus, the experience on production tools is directly contrary to the indications of impact tests.

It appears appropriate to apply the wisdom of a pioneer in material evaluation, H. W. Gillett*:

"A good engineer . . . thinks for himself and he maintains a healthy skepticism about measures that don't really measure. When he wants to know how a material is going to behave in service, he looks up what the handbooks have to say about it and finds it described in terms of conventional mechanical test values. But then he does not assume that those values tell anything more than how the material acts in the test. He does not assume that the behavior he wants in service is sufficiently implied by the conventional test results obtained under conditions not agreeing with service conditions.

"All in all, ductility values cannot be used directly in design. Even less direct application can be made of the figures for foot-pounds absorbed in a conventional notched-bar test, sometimes thought to measure toughness. There has been a wholly false impression that a material showing 40 ft-lb. Charpy is twice as tough and twice as good for severe service as one of 20 ft-lb. Equally false is the idea, expressed in some specifications, that some particular value, often that of 15 or 20 ft-lb. energy absorbed by a conventional notched bar, represents a safe level of toughness. These values tell the behavior of the particular size and shape of specimen, and nothing else."

*"What Do Material Tests Really Tell the Designer?", by H. W. Gillett, *Machine Design*, October 1949, p. 96, 102 and 154.

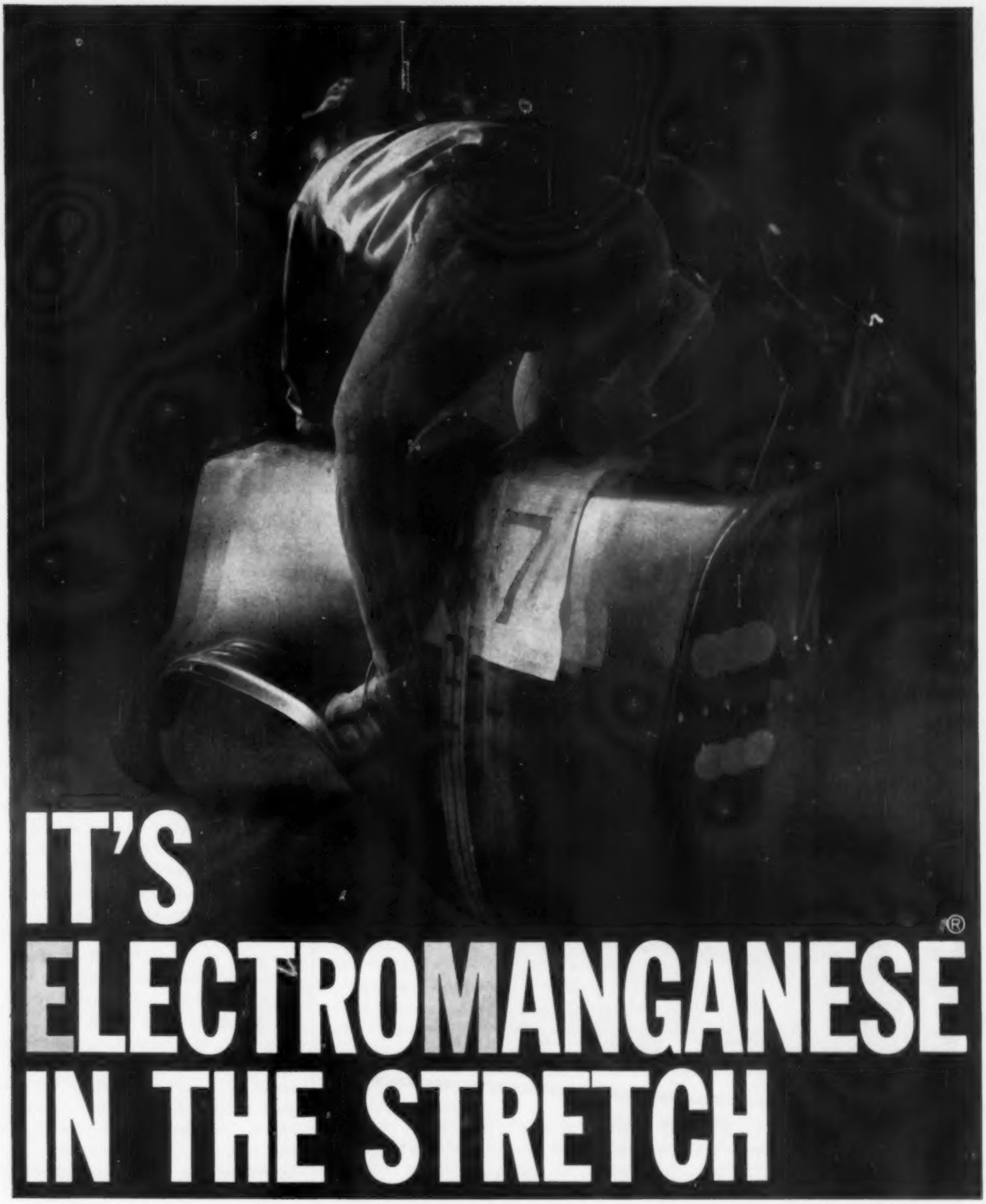
J. Y. RIEDEL
Toolsteel Engineer
Bethlehem Steel Co.

AUTHOR'S REPLY: I concur with Mr. Riedel that interpretation of the test results is the more challenging of the two – evaluation and application.

It is evident that one not skilled in the art of toolsteel application can be badly misguided by comparing numbers without regard to other factors, such as microstructure, operating stress system, and rate of load application. On the other hand, I feel that with an average background in toolsteel metallurgy one can readily compare steels which are metallurgically similar and select the tougher of two grades.

To cite the specific examples, in larger sizes the shallow hardening W 1 steel will have a tough core and a hard case in compression, insuring good fatigue resistance. The distribution of internal stresses in the through-hardening D-2 die, however, may or may not be conducive to long die life. This information was not implied in the test results presented in the article. Similarly, the impact resistance of high speed cutting tools must be examined in the light of tool performance experience.

On the other hand, the test data agree consistently with service experience which indicates that molybdenum-base high speed toolsteels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Correspondence . . .

(M-2) are generally tougher than tungsten base steels (T-1).

Similarly, the outstanding performance of LaBelle HT in many applications involving severe shock is paralleled by the high Charpy C-notch impact values of this grade.

We merely intended to present data on the toughness comparison of different steels using a test that appeared to be more selective than other tests used in the past. We did not wish to imply that toolsteel selection could be made on the basis of this test alone.

GARY STEVEN

A Further Look at Russian Steels

TORONTO, ONT.

We have read with great interest the excellent article "A Look at Russian Steels", by your consulting editor Arthur B. Tesmen, on p. 101 of the June 1959 *Metal Progress.*

However, we wonder about his source of information on the effect of arsenic content in the Kerch ores and in the Azovstal rails. According to the article: "In 0.75% carbon rail steels, 0.15 to 0.20% As was found to have no adverse effect upon strength and impact after aging nine months. Their investigations also established that weldability of rimmed and killed low-carbon steels was not affected until arsenic exceeded 0.20%. . ."

The above statement seems to be in contradiction to an original Russian article concerning the same Azovstal steels ("The Effect of Arsenic and Phosphorous on the Impact Values of Rail Steel", by L. M. Shkolnik, *Stal,* No. 6, 1956, p. 548-553). We quote two sentences from that articles' conclusions: "To avoid the influence of arsenic on impact values, it is necessary to decrease the phosphorous content of the steel; 0.1% As is compensated by decreasing the phosphorous 0.005% . . . The arsenic-contaminated Azovstal rails show a much lower impact value than the arsenic free rails of the same works."

Futhermore, the Czechoslovakian steel industry had to investigate the dangers of arsenic due to the growing import of the Russian Kerch ores. We quote here from the F. Benes (*Hutnicke Listy,* 1957, Vol. 1,

Correspondence . . .

p. 85-86): "It will be necessary to keep the arsenic content as low as possible with maximum 0.030 up to 0.040% to ensure the production of good quality steels. . . A positive method of arsenic extraction from the ores would be the only way in the future to prevent the arsenic content reaching the values which may be called critical."

P. T. Vajk
Metallurgist
British American Oil Co., Ltd.

Author's Reply: With reference to the effect of arsenic upon the properties of rail and low carbon steels, permit me to quote the conclusions of the article in *Stal* to which reference is made ("The Effect of Arsenic and Phosphorus on the Impact Values of Rail Steel", by L. M. Shkolnik, p. 553):

"1. While arsenic decreases the impact strength of rail, its detrimental effect is much weaker than that of phosphorus, especially at lower temperatures. The detrimental effect of phosphorus upon impact strength increases at lower temperatures while that of arsenic decreases.

"2. In order to minimize the influence of arsenic upon impact strength, it is necessary to reduce the phosphorus content; every additional 0.1% As can be compensated for by a decrease of 0.005% in phosphorus.

"3. While Azovstal rails containing arsenic have lower impact characteristics than those free of arsenic, is was found that the lower properties are due to the presence of phosphorus, rather than the arsenic."

Subsequent work at the Paton Electric Welding Institute (*Stal*, No. 7, 1956), Azovstal and Ukranian Institute of Metals (*Stal*, No. 8, 1958) have established that rimmed and killed low-carbon steel containing up to 0.20% As are weldable (one investigator allows up to 0.29% As) with no detrimental effect upon their mechanical properties, and that the impact characteristics of rail steels (aged nine months) were not detrimentally affected by presence of up to 0.13 to 0.25% As.

These findings agree with F. Benes' statement: "It will be necessary to keep the arsenic content to a maximum of 0.030 to 0.040%. . ."

Arthur B. Tesmen

Personal Mention

Walter R. Hibbard, Jr.

Walter R. Hibbard, Jr., manager of the alloy studies section of the metallurgy and ceramics department at the General Electric Research Laboratory in Schenectady, N. Y., was awarded the 1959 Yale Engineering Association Award for the Advancement of Basic and Applied Science. Dr. Hibbard was cited as a "scientist and engineer, metallurgist of international reputation . . . [who] has carried over into his industrial research affiliation a continuing interest in the teaching of our youth."

A graduate of Wesleyan University, he received his doctorate in physical metallurgy from Yale in 1942 where he subsequently served as assistant and later as associate professor. A member of the staff of the Research Laboratory since 1951, he has been active in the leadership of the American Institute of Mining, Metallurgical and Petroleum Engineers and American Society for Metals.

Two years ago he was one of a group of American scientists who toured Russia under the sponsorship of the U. S. State Department, studying Soviet education and research in the field of metallurgy.

Russell A. Hastings has been elected executive vice-president of the K. H. Huppert Co., Chicago.

Edward O. Falberg has been promoted to division manufacturing manager of Bohn Aluminum & Brass Corp., Detroit, with responsibility for the manufacturing operations of Bohn's plants in Greensburg, Ind., and Holland, Mich. For the past five years, Mr. Falberg has held various plant management posts with the company, and was assigned to the Greensburg plant before his recent appointment.

John G. Ziemann has been promoted to assistant chief metallurgist in the Metals Div. of Kelsey-Hayes Co., New Hartford, N. Y. Mr. Ziemann, who will be in charge of special projects in connection with alloy production, has been connected with the company since 1957 as a research metallurgist.

Arthur H. Vaughan, chief engineer of the Electric Furnace Co., Salem, Ohio, has been awarded the Trinks Industrial Heating Award. Mr. Vaughan was cited for his conspicious achievement in designing over 2900 special furnaces in a career spanning 27 years.

A. V. Orr was recently appointed manager, Canadian sales, for Atlas Steels, Ltd., Welland, Ont. Mr. Orr has served as sales engineer for Atlas in the Vancouver, Toronto and Niagara districts and more recently as manager of toolsteel products for the company.

C. F. Koehler, Jr., was appointed assistant vice-president of Wyckoff Steel Co., Pittsburgh, at the recent annual stockholders meeting of the company.

Manuel Tama has been named vice-president in charge of the Ajax Magnethermic Corp. engineering division in Trenton, N. J. Mr. Tama has been with Ajax since its formation in 1941 as vice-president and since 1938 as president. Earlier this year, two Ajax companies were joined with the Magnethermic Co. to form Ajax Magnethermic Corp.

Arthur W. Donkin recently joined Mechanical Spring Fabricators, Inc., Chicago, as vice-president and general manager. He was formerly associated with the development department of Air Reduction Sales Co., Union, New Jersey.

K. H. Carlson has been appointed technical manager of specialty steels for the Latrobe Steel Co., Latrobe, Pa., in charge of technical development and service.

Dillon Evers has been named manager of the sponsored research group, a newly formed department at Mallory-Sharon Metals Corp., Niles, Ohio, created to carry out research and development projects on special metals for the government. Dr. Evers joined Mallory-Sharon in 1956 and until his recent appointment was staff technical advisor to the company's research and development department.

Martin J. Dempsey has been appointed product metallurgical engineer in the Crucible Steel Co. of America's technology department, assigned to the Pittsburgh office. Formerly manager of the company's Detroit sales branch, he joined Crucible in 1941 as a metallurgist at the Spaulding Works in Harrison, N. J., transferring to Pittsburgh and then the Detroit sales branches.

Edward J. Mammana was recently assigned to the New York district office of Riverside-Alloy Metal Div., H. K. Porter Co., Inc., where he will cover portions of the New York City area from the division's office in East Orange, N.J. Mr. Mammana, who was formerly associated with Crucible Steel Co. of America in a sales-service capacity, joined the company in February and received his appointment after completing an intensified mill familiarization course.

O. M. Haseltine has been named sales manager of Ajax Electric Co., Philadelphia. A charter member of the Chicago-Western Chapter, he formerly served Ajax as sales engineer in the Chicago and Midwest territory.

Italo S. Servi has been named director of research in charge of all research and development activities for the Metals Div., Kelsey-Hayes Co., New Hartford, N. Y. Dr. Servi had been affiliated with the Union Carbide Metals Co. research laboratories at Niagara Falls, N. Y., since 1951, and last held the post of manager of the corporation research group.

Personals . . .

Kenneth P. Seeger is now chief metallurgist on the staff of Precision Extrusions, Inc., Bensenville, Ill. Active in the aluminum extrusion field for the past 18 years, Mr. Seeger was formerly plant metallurgist for the Aluminum Co. of America at Lafayette, Ind.

Thomas H. Mitchell has joined Calstrip Steel Corp., Los Angeles, as metallurgist in charge of quality control for stainless steel strip, low-carbon and spring steel strip.

Russell V. Bobb, assistant manager of the extrusion division of Reynolds Metals Co., Richmond, Va., has taken over supervision of the company's extrusion plant in Phoenix, Ariz.

E. L. Milford, a veteran of 18 years' experience in the heat treating industry, has been appointed sales engineer in the Chicago and midwestern area by Ajax Electric Co., Philadelphia.

Ralph D. Wysong, manager of manufacturing research for Studebaker-Packard Corp., South Bend, Ind., was recently elected national president of the American Electroplaters' Society at the organization's Golden Jubilee Convention, held in Detroit.

Louis V. Abrams, recently employed in management consultant work, has joined Pangborn Corp., Hagerstown, Md., in the newly created post of administrative assistant to the president.

George E. Meyer, formerly at Rensselaer Polytechnic Institute, has joined the staff of the Oak Ridge Y-12 Plant of the Union Carbide Nuclear Co. in Oak Ridge, Tenn. At the same time, **Ralph G. Donnelly** and **George Hallerman**, from Case Institute of Technology and Columbia University, respectively, have become members of the Oak Ridge National Laboratory.

Adam MacKenzie has been appointed marketing manager of the General Electric Co. lamp metals and components department in Cleveland. Associated with General Electric for 35 years, he was formerly manager of the department's Cleveland weld plant.

J&L, too, relies on *Lee Wilson* single stacks for finest chrome-stainless annealing!

No special atmosphere required... uniformity of physical properties declared excellent—Exacting uniformity of anneal is particularly desirous in chromium stainless steels. To make sure of the finest possible annealing Jones & Laughlin selected Lee Wilson single stack furnaces for their new Stainless and Strip Division plant at Louisville, Ohio.

No special atmosphere is required. The anneal develops a type of scale which is easily removed. The four furnaces and eight bases have capacity for 2800 tons per month.

Designed specifically for stainless annealing the installation includes cast alloy convector plates, oil-lubricated fan drive and alloy fan wheel designed to operate up to 1600°F. Because charges are uncovered at high temperatures heat shields have been installed between bases.

Standard or special Lee Wilson single stack furnaces are unequalled when it comes to quality, production and versatility.

Jones & Laughlin can process 2800 tons per month of chrome-stainless through the four Lee Wilson single stack annealing furnaces pictured above.

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Personals . . .

Amos J. Shaler ⊕, head of the department of metallurgy at Pennsylvania State University, is on a year's sabbatical leave in Belgium, with headquarters at the European Research Associates research laboratory in Brussels. This group will be sponsoring some of his work in Europe. During the next year, he will do some writing, study in the field of nuclear materials, do a little research in powder metallurgy and travel to universities, research laboratories and industrial plants.

John G. McMullin ⊕ has resigned as supervisor, metallurgy applied research, for the large steam turbine-generator department of General Electric Co., Schenectady, N. Y., to accept a position as supervisor, structural alloy research, in the central research laboratory, Crucible Steel Co. of America, Pittsburgh.

Adna A. Armstrong ⊕, formerly manager, process control laboratory, valve division, Thompson Ramo Wooldridge Inc., has been appointed manager of metallurgy for Burgess-Norton Mfg. Co., Geneva, Ill.

Richard J. Quigg ⊕ recently received his doctorate degree from Case Institute of Technology and is now employed as a research metallurgist for Thompson Ramo Wooldridge Inc., Cleveland.

David L. McElroy ⊕, formerly associated with the University of Tennessee, and **Thomas D. Watts** ⊕, from the University of Wisconsin, have been appointed to the staff of the Oak Ridge National Laboratory, Oak Ridge, Tenn.

John J. Horner ⊕ has been promoted to industrial manager of the Philadelphia branch office of Minneapolis-Honeywell Regulator Co. Mr. Horner has been with Honeywell since 1937, as an industrial service engineer and then as a salesman.

Peter Leckie-Ewing ⊕ has joined the metallurgical staff of Latrobe Steel Co., Pa. He was formerly associated with Landis Machine Co. of Waynesboro, Pa., in the position of chief metallurgist.

William P. Ziegler, Jr., ⊕ has been appointed national sales manager of Kolene Corp., Detroit. He joined the company in 1949.

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FREDDIE FLEXAL invites your further inquiry.

Swift's new line of high heat resistant, long mileage lubricants are now available to serve a variety of drawing and metal processing jobs.

Flexals are extremely versatile. A wide range of chemical and physical properties makes them particularly adaptable for difficult or highly specialized jobs. For example: Flexals can be furnished for cold heading, hot dip coating and dry drawing of high or low carbon wire. They can be soluble in water . . . or *insoluble* in both water and solvents. Melting points range to 800° F. They are offered in controlled grinds down to micron particle size.

Look over Swift's new *Family of Five* FLEXALS . . . with *your* process in mind. Then, write for details on a trial order of these versatile new ANTI-FRICTION lubricants.

FLEXAL S	Hot dip, dry film lubricant and rich, dry drawing compound.
FLEXAL CS	Fine calcium stearate; 58°-60° C. titer, 325 mesh.
FLEXAL MCA	Metallic stearate base. Medium vari-grind compound.
FLEXAL MCF	Metallic stearate base. Rich, fine mesh drawing compound.
FLEXAL MCL	Lean, fine, dry lubricant for low carbon bright and cold heading wires.

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Personals . . .

Julian Glasser and **William E. Few** are now associated as consultants in chemical and metallurgical activities in Chattanooga, Tenn., offering services to industry and government. Mr. Glasser, formerly technical director at Cramet, Inc., Chattanooga, had been operating a consultant practice for the past year, while Mr. Few was technical assistant to the general sales manager, alloy and metal division, Tennessee Products and Chemical Corp., Nashville, Tenn.

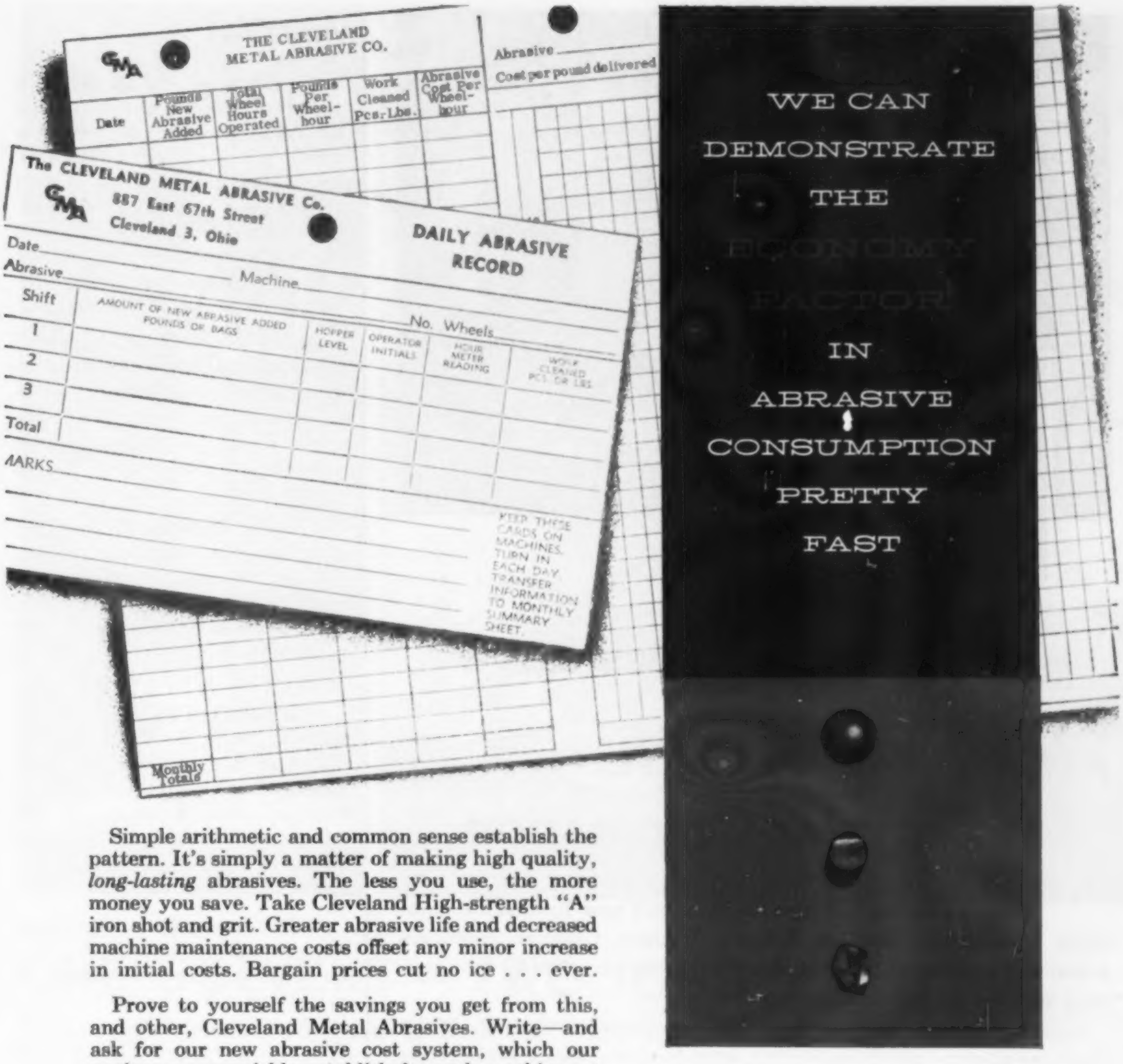
Charles N. Zimmermann has been appointed senior sales engineer for the New England territory of the Brush Beryllium Co., Cleveland, with headquarters in Boston. At the same time, **L. Dean Alspach**, formerly sales engineer for the company, was promoted to district manager in charge of sales territories in Indiana, Ohio, Kentucky, Western New York and Eastern Ontario. Mr. Alspach was a founder of Penn Precision Products in Reading, Pa., now the Pennrold Div. of Brush.

Daniel S. Steelman was recently named director of purchasing by Fischer & Porter Co., Hatboro, Pa. Formerly purchasing agent, Mr. Steelman has been with the company for 17 years.

David W. Mitchell has been assigned as coordinator, research and production, for Foote Mineral Co., Philadelphia. In addition to his new assignment, Dr. Mitchell will continue to act as manager of minerals research. He will be located at the company's research and development laboratories in Berwyn, Pa. Since joining Foote in 1957, he has been engaged in mineral beneficiation research at the lithium mine at King's Mountain, N. C.

John H. Dasdorf has been assigned to the Los Angeles district office of Jones & Laughlin Steel Corp., Pittsburgh, as a service metallurgist, stainless and strip division.

George O. Hiers, consulting metallurgist, Baldwin, N. Y. was presented with an award of merit in recognition of his long-time active participation in A.S.T.M. work especially in the field of nonferrous metals.



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Personals . . .

Bernard Kopelman has been appointed technical director for the Beryllium Corp., Reading, Pa. He joined Sylvania Electric Products' central research laboratories in 1944 and ten years later became chief engineer of the newly formed Sylvania-Corning Nuclear Corp. In 1958 he rejoined Sylvania as manager of electroluminescent engineering.

Donald C. Atkins has been named director of the new technical department of United States Chemical Milling Corp., Manhattan Beach, Calif. For the past two years he has been assistant chief engineer for the concern.

Karnig A. Berberian has joined Tang Industries, Waltham, Mass., as manager of materials. He was formerly employed by Raytheon Co. in the semiconductor division as pilot plant materials engineering group leader.

Henry Hubbell, formerly chief metallurgist for the Fafnir Bearing Co., New Britain, Conn., has been promoted to technical development manager. **Philip K. Pearson, Jr.**, who joined the Fafnir metallurgical laboratory in 1950, will succeed Mr. Hubbell.

C. H. Toensing, for eight years research and development engineer for the lamp metals and components department of General Electric Co., has been appointed manager, powder metals research at Firth Sterling Inc., Pittsburgh.

Norman D. Groves and **Neil J. Culp** have been promoted to assistant managers of research in the metallurgical department of Carpenter Steel Co., Reading, Pa. Mr. Groves, a corrosion engineer for Carpenter since 1956, was named assistant manager of research in charge of chemistry and physics, while Mr. Culp, formerly supervisory metallurgist of the alloy development group, was made assistant manager of research in charge of metallurgy.

Daniel L. Wertz is now directing the development and marketing of a new line of automated batch-type controlled atmosphere furnaces. Mr. Wetz is a past chairman of the Detroit Chapter.

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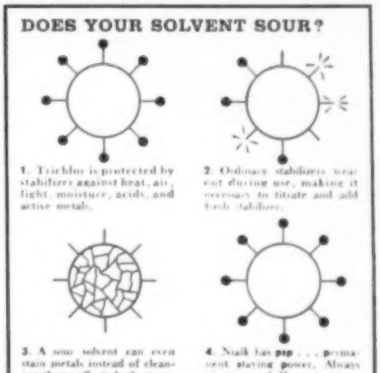
Send for bulletin. Data Sheet 814 should answer any questions you have about Nialk trichlor. Write for a copy.



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Solid Lubricants

A digest of "Solid Lubricants", by A. J. Stock, Acheson Colloids Co., Port Huron, Mich. Paper presented before the American Society of Lubrication Engineers, Buffalo, N. Y., April 21, 1959.

SOLID LUBRICANTS have many advantages. Unlike liquids, they cannot be squeezed out when two surfaces approach boundary lubrication conditions. They will retain their lubricating properties over a long period of downtime. (No relubrication is necessary after extended periods of storage.) They can be relatively insensitive to high temperatures, extreme atmospheres and vacuums. Their excellent load-carrying capacity makes them valuable where fluid lubricants would break down.

Of course, there are certain disadvantages. Before tetrafluorethylene resin (TFE) dispersions were developed, solid lubricants were black, and could not be used widely where personnel would contact them. Also, solid film lubricants do not dissipate heat as well as do metals in conjunction with fluid lubricants. Thin films of solid lubricants are not self-healing so they do not last as long as a fluid system in which the fluid can be changed and renewed continuously. Although solid lubricants have exceedingly low friction coefficients, they are still not as low as those obtained with normal lubricating fluids. One must always balance these advantages and disadvantages when considering solid lubricants.

Solid lubricants can theoretically be used in four ways: bulk solids, thin films, dispersed in liquids, or dispersed in greases. All are useful to industry. Today, the most important types are graphite, molybdenum disulphide and the various plastics such as nylon and Teflon*.

Graphite, the first solid lubricant to be extensively used, is a lamellar solid. In other words, carbon atoms are in layers with certain well defined patterns. Cohesive forces between the layers of carbon atoms are much weaker than the forces between the atoms in the layers. One theory maintains that slippage between planes gives the lubrication effect. Graphite, of course, is pure carbon and it is obtained either from natural or synthetic sources. It retains its excellent friction qualities and inertness to chemical reaction to 1000° F. and above.

The second familiar solid lubricant is molybdenum disulphide. Another lamellar solid, this is a chemical compound in which alternate layers are formed of molybdenum and sulphur. It has about the same low friction as does graphite. In addition, it has a higher resistance to load. This makes it very useful for extreme pressure applications. However, molybdenum disulphide does not have the chemical resistance of graphite. Also, when it decomposes, it forms various hard oxides which can grind rather than lubricate. Because of this, the friction, although low at room temperature, rises quite severely above 700° F. Molybdenum disulphide thus finds much use where extremely low frictions, high loads and relatively low temperatures are combined.

The third significant solid lubricant is tetrafluorethylene resin or TFE (duPont's Teflon). This is a plastic and is much used for its very low friction coefficient (about 0.04). So far, TFE and other plastic lubricants have been used as bulk solids, as thin films or as grease additives. (It has excellent chemical and thermal resistance up to about 600° F. Relatively soft, it performs best as a thin film particularly when combined with bonding resins. It is also rather hard to wet and it sticks poorly, which can sometimes be advantageous.

Another important plastic lubricant is nylon which is mostly used in bulk solid for bearings. Though not as low in friction as TFE resins, it is much harder and can be used without lubrication where the loads are relatively high and speed is low. It is not overly resistant chemically or thermally. However, its low price, compared to TFE, makes it much more useful in ordinary applications. (*Cont'd. on p.* 148)

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Thirty-two ton Kemp Immersion Melting Pot keeps production on a 24 hour basis at Stanley Works, New Britain, Conn. Steel strapping is annealed on a continuous basis with important savings in time and fuel costs.

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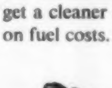
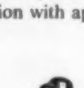
This kind of efficiency pays off with a better finished product at lower cost. You can forget about delays, cracked pots, exposed flame, and wasted down time. With Kemp Immersion Heating Unit at work for you, you can expect the finest performance of its kind—the result of a quarter century's pioneering experience.

Capacities from 1 to 75 tons—melting rates up to 26 tons per hour. For more information and practical suggestions, call in your Kemp Representative or write us direct for Bulletin IE-11. *The C. M. Kemp Mfg. Co.*, 405 E. Oliver St., Baltimore 2, Md.



Convection Dryers



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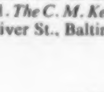

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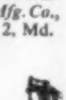

Oriad Dryers

Solid Lubricants . . .

Sapphire and diamond can be considered to be solid lubricants since they exhibit low coefficients of friction against steel. Many salts also exhibit the properties of solid lubricants, but most suffer from chemical sensitivity, thermal sensitivity, or other deficiencies which limit their use. Lead oxide and boron nitride lubricate well at high temperatures. However, both show undesirable higher frictions as the temperature drops.

Conditions Affecting Uses

In thin films, the relative thinness makes their use very dependent on many factors. For example, if the substrate is very hard, it backs up the film, and much lower forces are needed for motion. Similarly, the surface of the substrate is very important. If it is quite smooth, the film will adhere poorly. Thus, it is normally suggested that the substrate surface be pretreated by phosphatizing, sand-blasting or etching to allow better binding of the thin film.

Stainless steel is usually vapor-blasted for adherence of the thin film lubricants, while iron surfaces are best phosphated. Indeed, they may also be sand-blasted before phosphatizing. However, some of these pretreatments, especially the chemical ones, are sensitive to high temperatures; therefore, the desired pretreatment must be balanced against the use conditions.

Thin film lubricants are very sensitive to the atmosphere in which they are being used. Graphite will not work as a lubricant if it is heated in a vacuum; it needs an amount of absorbed gas to insure lubricating properties. This is not true of molybdenum disulphide or Teflon and nylon. On the other hand, too high humidity will lead to corrosion problems.

Naturally, load and speed are also important conditions to be watched when using thin films. Unfortunately, no generalizations are possible because each thin film lubricant is composed of different resins and different solid lubricants. Thus the properties of each thin film solid lubricant depend mainly on conditions of use and makeup of the film.

Dispersions in greases or liquids

depend greatly on the dispersing medium. This can be an oil, solvent, water, grease, silicone, or a number of other special fluids. The amount of the solid lubricant dispersed in the system, because of cost, is limited to that needed to give correct lubrication. Of course, there should be enough so that there will always be solid lubricant available.

Another very important condition is the particle size. For very thin solvents of low viscosity and for boundary conditions particles should be fine to reduce settling and constant lubrication. However, in metalworking, where the friction action actually occurs only once, particles can be larger.

Temperature, load and speed are also important. Stability is somewhat affected by high temperature. The dispersion medium must be suitable to the load and speed which are going to be occurring in the system. Each application must be reviewed by itself and the dispersing medium, dispersed solid, and properties such as viscosity and solids content must be chosen to make for the best service. There is no set answer to the question of what type of lubricant will be used for what load and what speed.

Uses of Solid Lubricants

Colloidal graphite in water was first used in wire drawing. No other lubricant is so well adapted to fine tungsten and molybdenum wire; its use enables wire to be drawn through diamond dies with a minimum of effort and a maximum die life. Colloidal graphite in oil is frequently used as an assembly lubricant for gear trains and piston engines, or compressors. A dispersion of graphite and naphtha is widely used in deep drawing magnesium and other light metals. The solvent rapidly evaporates leaving a very smooth thin film of graphite which allows the metal to flow smoothly without tearing or sticking on the die surface.

Colloidal molybdenum disulphide in petroleum oil is frequently used for extreme pressure applications and as an additive for greases. Both colloidal molybdenum disulphide and colloidal graphite are employed in special fast evaporating solvents such as isopropanol. These films provide a rapid-drying, dry film lubricant which prevents galling in

Solid Lubricants . . .

press fitting and assembly operations where lubrication is needed only once.

In addition, both graphite and molybdenum disulphide are dispersed in many other unusual vehicles such as glycols, silicones, and other special organic vehicles resistant to oxygen or high temperatures. In many instances, the lubricating action is due only to the dispersed solid.

Both graphite and molybdenum disulphide are also dispersed in numerous types of resins systems. Coated on metals and then baked or air hardened, these provide a permanent solid film lubricant. They are used on nuts and bolts for assembly purposes in the aircraft industry, for business machine parts, for places where lubrication must be a one-time proposition and for places where normal fluid lubricants would be chemically unstable. Recent developments have made it possible to disperse TFE in resin solutions; this provides lubricants which are white or various colors rather than the black of molybdenum disulphide and graphite.

Some solid lubricants are used in powder form but this is probably limited. The handling of dry powders is so difficult that manufacturers prefer to deal with the bulk solid or with liquid dispersions.

C.R.W.

Hot Tears in Cast Steel

Digest of "Metallurgical Aspects of Hot-Tearing in Cast Steel", by Kurt Beckius, *Foundry Trade Journal*, Vol. 104, Jan. 30, 1958, p. 115-123; Feb. 6, 1958, p. 149-153.

RECENT STUDIES of basic hot tear mechanisms and the delineation of factors known to influence hot tearing in castings have proven of significant value. Investigation was conducted at the Royal Institute of Technology, Stockholm.

Experimentally, solidification and hot tearing characteristics of numerous specimens were studied under conditions that would quantitatively reveal the influence of composition, temperature, cooling rate, and specimen size and geometry. The basic apparatus consisted essentially of a

Lindbergh carbonitriding furnace at Western Automatic. Gulf Super-Quench is used in the internal bath.

Licks valve warpage problem, gets uniform hardness and cleaner finishes with Gulf Super-Quench

Take it from Bryan W. Miller, Heat Treat Foreman at Western Automatic Machine Screw Company, Elyria, Ohio—you can solve many of your quenching problems with Gulf Super-Quench.

"We used to have quite a warpage problem in the quenching of automotive valves made of B 1113 steel," reports Mr. Miller, "attributable to nonuniform cooling throughout each piece. But with Gulf Super-Quench we're able to hold expansion on these valves to within .003" and also maintain uniform hardness. What's more, we get clean finishes that need no sandblasting."

What makes Gulf Super-Quench so effective? It's the dual action of fast quenching through the hardening range and slow cooling in the critical distortion range. Result: Gulf Super-Quench assures deeper and more uniform hardening, less distortion, and clean, bright work.

You too can obtain better results from many of your quenching operations with Gulf Super-Quench. For proof, just call a Gulf Sales Engineer at your nearest Gulf office.

Gulf man on the job. Left, T. F. Irving, Gulf Sales Engineer; right, Bryan W. Miller, Heat Treat Foreman, Western Automatic Machine Screw Co.

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Hot Tears . . .

device for measuring longitudinal contractions of a cylindrical specimen during solidification and cooling. The specimen (of a tapered design) established temperature gradients and localized hot tears. Normal contraction of the specimen was restrained by a spring-loading mechanism that initiated and accentuated hot tearing during solidification. Data were plotted in terms of time-versus-contraction curves for each of the conditions studied, and corresponding photomicrographs were then used to indicate the correlation between microstructure and hot tearing characteristics.

From his analysis of the results, the author concludes that hot tears are usually initiated just below the freshly solidified surface of the casting, and then extended both inwardly and outwardly, eventually reaching the surface. Supplementing this conclusion, the following explanation of the mechanism of hot tearing is offered. (It is noteworthy that certain aspects of the author's explanation do not agree entirely with those of previous investigators.)

When molten steel comes into contact with the wall of the mold, a very thin shell of solid steel forms and becomes continuous from one end of the specimen to the other. Due to heat loss through the walls of the mold, the shell will steadily decrease in temperature, and contract. When this contraction in the solid shell takes place freely (that is, unhindered by surface friction or external restraint), contraction will then proceed without the development of any stresses or resulting strains in the shell. On the other hand, with great surface friction, the shell will be locked at numerous points on the contact surface with all movement or contraction replaced by a uniform stress along the entire shell. In these instances hot tearing would not be expected. In the latter instance, however, stresses could be dissipated in the solidified shell by plastic deformation. Thus, as long as the shell is quite thin and there is good contact between the mold wall and the steel, such stresses and the accompanying plastic deformation may lead to hot tears in the shell. The resulting tears may then continue outwardly to the surface,

ACHESON

dispersions digest

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Efficiencies realized by just one company — with the help of Acheson Dispersions — have already added up to this substantial savings. Uniform coverage, easy sprayability, and lasting lubrication effectiveness are providing this leading forgings producer: longer die life, increased production, fewer rejects, and improved forgings. This lubricating success story is being repeated throughout the metal working industry. Possibly *you* could profit from the use of an Acheson Dispersion.

'Prodag' application on forging presses at Mueller Brass Company has saved between $15,000 and $17,000 annually for the past fifteen years. These impressive savings earned by this Port Huron, Michigan company — the world's largest producer of brass and bronze forgings — have been realized in many areas.

Previously, crank forging pressmen at Mueller swabbed the dies between each press stroke. Mueller designed their own spray apparatus, both manual and automatic, to lubricate lower and upper dies simultaneously. Time studies have shown that spraying has effected a five percent-per-pound economy over the swab method.

Spray application of 'Prodag' at Mueller Brass Company has resulted in impressive production savings.

Even more importantly, by using Acheson's 'Prodag' — a dispersion of graphite and water — diluted 1:35, Mueller has gained longer die life, reduced the percentage of scrap loss, and has obtained a better finish on their forgings. According to Mr. O. M. Hanton, Chief Forging Engineer for Mueller, "with 'Prodag' we get the right amount of lubricant on the die. Swabbing resulted in too much lubrication at one place or another in the die cavity, resulting in either a ruptured die or a defective part. Previously, every forging produced had to go to the grinding department. And grinding is one of the most expensive operations in a forge shop."

In producing deep-cavity forgings, or products which demand much smaller tolerances, Mueller uses 'dag' No. 3 — another of Acheson's graphite-water base dispersions. If you have a forging lubrication problem it will pay you to call in your Acheson Service Engineer or write for Bulletin No. 426.

'dag' 35, brush-applied to the slides of this rollover machine, increases machine life for this midwest foundry.

An expensive foundry problem was solved for the D. J. Murray Manufacturing Company, Wausau, Wisconsin, with the use of Acheson's 'dag' 35 — colloidal graphite in an alkyd resin solution. Slides on the huge rollover machine installed in their foundry division, previously lubricated by first a dry graphite and then rosin, were becoming deeply scored as a result of its 90-cycle-a-day operation in the handling of bench and floor molds.

The scoring and machine vibration was so severe that according to Maintenance Foreman, Ben Sayles, "we could see that the life of the machine was going to be very short if we continued this method of lubrication." Coating the slides daily with 'dag' 35, improved machine operation immediately. The scoring all but disappeared. After two years of application with this Acheson dispersion, no repairs have been necessary and none are foreseen. Since the entire production of their grey iron sand slinger line — some 60 tons of material in 8 hours — goes through this machine, the downtime avoided represents an important savings to the company.

For additional information, write for Acheson Bulletin No. 425. Address Dept. MP-99.

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Hot Tears . . .

but they do not always do so. The governing factors are the ductility of the shell and the magnitude of the resistance to contraction. If the resistance to contraction is overcome at a certain shell thickness, the tearing then ceases.

If, as in the present experiments, the contraction is restrained by the resistance of a spring, the force of friction will be augmented by a force directly proportional to the contraction thus leading to more active tear formation and giving rise to ruptures at numerous points of weakness.

In a columnar or dendritic structure, tears once formed expand very readily between the dendrites since the latter grow in straight parallel planes. Thus the structure offers little resistance to tearing, resulting in a practically simultaneous splitting over the entire periphery of the specimen. In a fine, equiaxed grain structure, hot tears will develop only at certain points where the crystal orientation is favorable in relation to direction of tensile stress. Thus, when a tear meets a less favorable crystal direction, it usually stops growing and a new tear forms at a more favorable point. This results in numerous minute tears rather than in gross splitting or fracture.

In his closing statement, the author acknowledges that conditions in the foundry are naturally more complicated than those encountered in the laboratory. However, the basic mechanism of tearing in actual castings should be the same, although the extent of tearing would depend upon the degree of localization of temperature gradients and on the amount of resistance to contraction. To avoid hot tears in practice, it is naturally important to choose a design of casting, mold material, and gating and risering system such that tear producing stresses are minimized or eliminated. If this is not feasible, the risk of hot tears can be further minimized by a suitable choice of steel composition and deoxidation practice.

W. W. Austin

Abrasive Belt Grinding of Zirconium Sheet

Digest of "Surfacing of Zirconium Alloy Sheet by Abrasive Belt Grinding", by H. N. Dyer and R. A. Leggett, Behr-Manning Co., Troy, N.Y.

BONDING ZIRCONIUM SHEETS together is an important step in the fabrication of fuel elements for atomic reactors. Preliminary preparation of the sheets – they are used to clad the fuel elements – must yield flat uncontaminated surfaces, otherwise the gas-bonding process will not effectively unite them with a good metallurgical bond. The best bonds are obtained from sheets which have been roughened uniformly and are free of embedded grit and chemical contaminants. Abrasive belt grinding can do the job effectively and economically.

The authors investigated the ef-

Belt Grinding . . .

fects of abrasive belt speed, type of grinding fluid, and type and size of abrasive grain on bonding qualities of reactor-grade Zircaloy-2 (hot and cold rolled). Bonding was accomplished by sealing surface-ground sheets in a protective container from which air had been evacuated. The assembly was then heated at 1550° F. in a helium atmosphere at 10,000 psi. Mating sheets bond by diffusion and grain growth.

For this investigation, the Zircaloy sheets were ground with aluminum oxide and silicon carbide belts running on an X-serrated, 80 durometer rubber contact roll. Belt speed varied from 1100 to 5500 ft. per min. and two grinding lubricants (tap water and a heavy sulphur-chlorinated cutting oil) were tried. Feeding rate of the sheets through the grinder was maintained at 4 ft. per min.

Surfaces abraded with 60-grit silicon carbide belts, run at 1500 to 3000 ft. per min. with a sulphur-chlorinated grinding oil, produced the best bonds. The total amount of metal removal is not critical except, of course, a new surface must be exposed by the operation. Good bonds are obtained from both hot and cold rolled Zircaloy (see Fig. 1). None of them could be broken when peel tested (driving a chisel into a V-notch at the interface). Twelve out of thirteen bonds did not corrode during exposure to steam at 750° F. for one week.

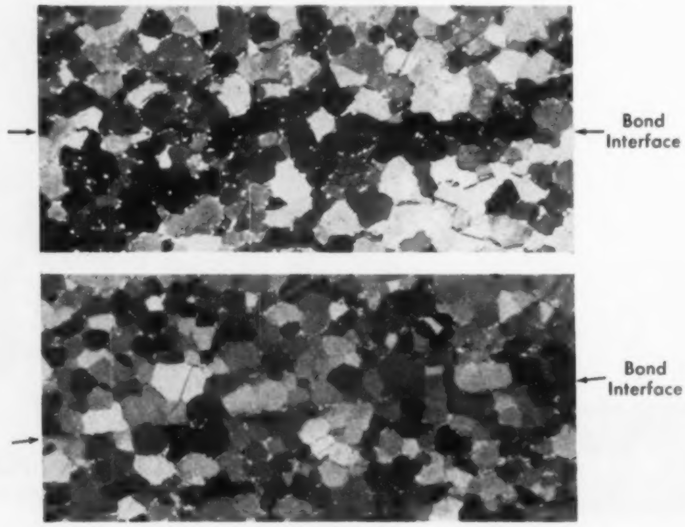
While grinding zirconium, an extremely hot, intense spark is produced, and fire-prevention measures are necessary when oil-base lubricants are used. Low belt speed, a heavy flood of oil (flash point above 350° F.), and an efficient filter to remove chips from the lubricant are recommended. R.G.D.

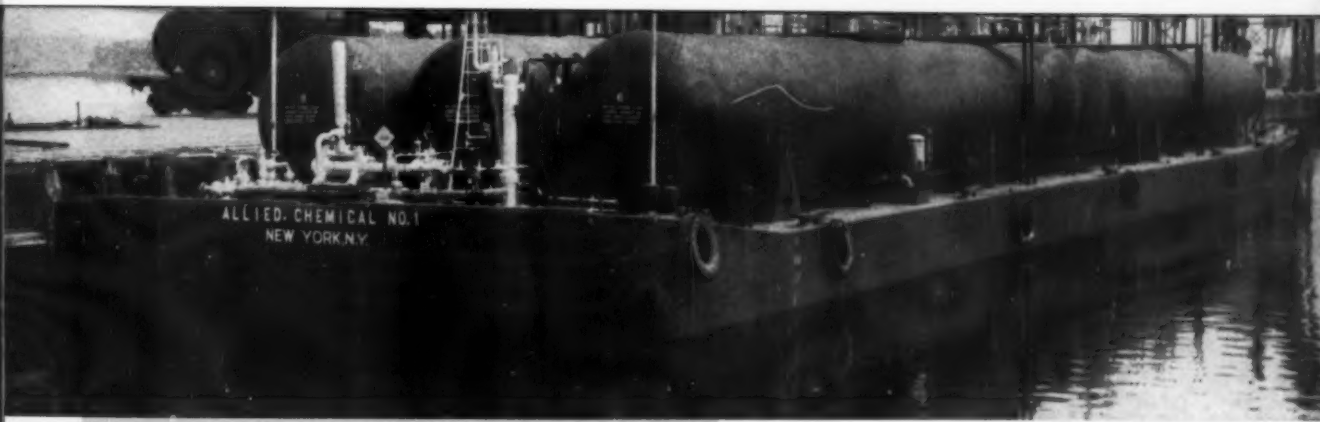
Hot Forming Magnesium Alloys

Digest of "Hot Forming Assembling and Service Applications of Magnesium Alloys", by R. G. Wilkinson, *Journal*, Institution of Production Engineers, Vol. 36, April 1957, p. 224-237.

THIS PAPER presents a broad but brief survey of shop fabricating practices and applications in British and American aircraft industries. Less than 10% of the magnesium used in the United Kingdom has been in the form of wrought materials, while in the United States the proportion has been around 30% and even as high as 50% in 1950. Illustrations of typical magnesium applications taken from American sources

Fig. 1 – Photomicrographs Show Influence of Prior Treatment on Bond Quality Obtained From Gas-Pressure Bonding of Zircaloy-2 Sheets. Top – typical bond between belt-abraded sheets (hot or cold rolled); bottom – poor bond between vapor-blasted and pickled sheets. Both photomicrographs taken in polarized light. 250×





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Hot Forming . . .

are the use of 7500 lb. of magnesium sheet in the B-36 by adhesive bonding, the tail cone assembly of the B-47, and the all-magnesium F-80 airplane.

The advantages of hot forming magnesium are:

1. More severe deformation is possible.

2. Reduced springback gives better dimensional accuracy of parts.

3. Smaller press capacity is obtained because power requirements are reduced.

4. Dimensional control of parts by regulation of tool and parts temperature is often possible.

Shearing, blanking or punching is satisfactory in the preparation of blanks on material up to 0.080 in. and under special conditions on thicknesses up to 0.160 in. Fixed head or radial arm routers having speeds up to 20,000 rpm. are used to cut the heavier thicknesses to avoid rough or flaky edges.

Forming tools must withstand temperatures up to 600° F. Magnesium alloy tools can be used for small production runs. Other tool materials are mild steels, toolsteels, chromium-plated or nitrided steels, plain or Meehanite cast iron, aluminum, Kirksite, antimonial lead, concrete and plaster protected with glass-fibre cloth.

Graphitic lubricants are used for severe forming while waxes and high-temperature oils are used for mild forming. The latter are more easily removed from formed parts than graphite.

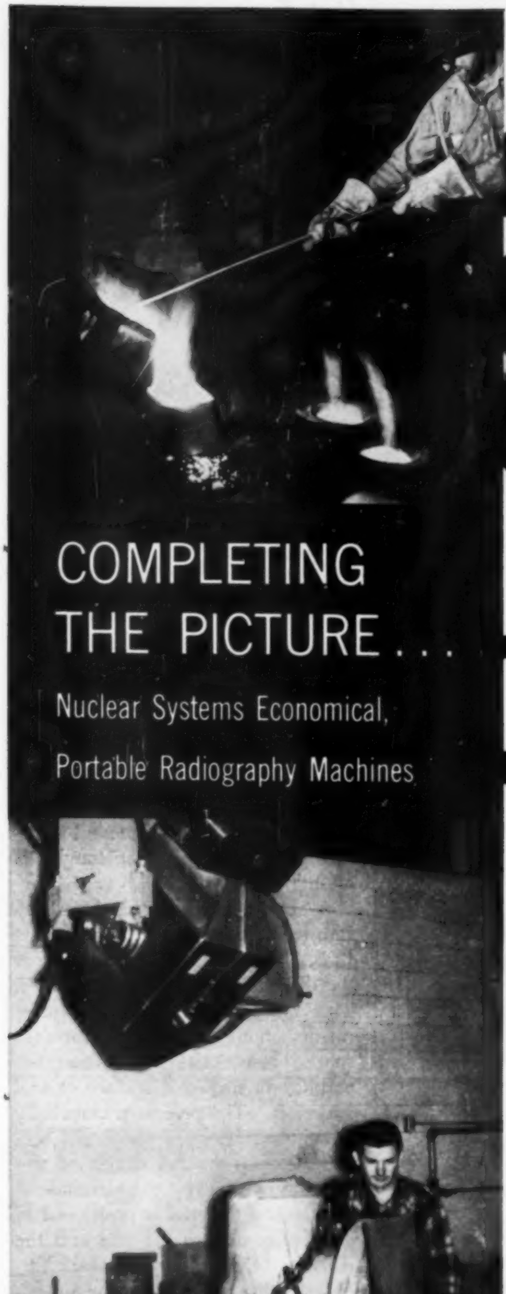
A good deal of hand forming is done in the United Kingdom because of lack of large quantity production. Consequently, the description of the forming methods, such as deep drawing, hammer forming, stretch forming and spinning, seem to be based largely on American practices. In bending, the British alloys possess a minimum 90° cold bend radius of 5 T, but 10 T (bend radius based on material thickness) is more usual. For hot working, these became 1 T and 4 T, respectively.

Single draws to a depth three to four times that for cold steel or aluminum can be made.

Surface Protection and Assembly

Protective treatments and finishes introduced recently in the United States are the anodic treatments HAE and CR-22, developed by Frankford Arsenal, and the Dow No. 17, developed by the Dow Chemical Co. In the United Kingdom they are the fluoride anodizing and surface sealing treatments. In the latter, the epoxy resin Araldite 985 E is applied over the anodized and chromated surface.

Protection against bimetallic corrosion in assemblies is obtained by the use of insulating strips, washers, chromate-containing sealers, and cadmium-plated steel screws or bolts. (Recent American developments indicate that tin-plated screws and bolts are more effective.) Protection in riveted assemblies is obtained by use of L 58 (95% Al, 5% Mg) or L 57 (duralumin) aluminum alloy rivets dipped in protective com-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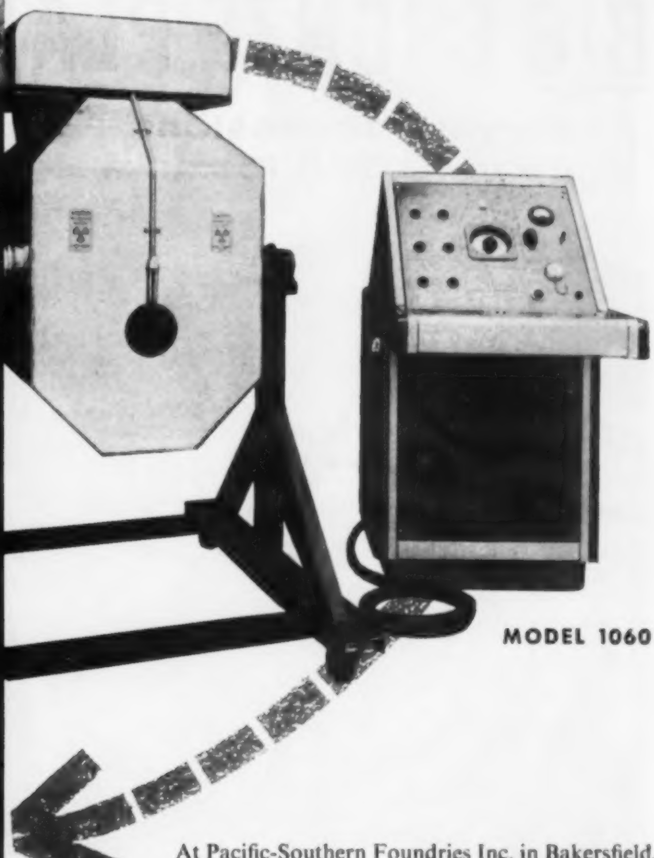
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Hot Forming . . .

pounds. Riveting procedures are summarized in some detail.

The good weldability of nearly all the highest strength magnesium alloys is advantageous in fabrication of many parts. Typical British and American welded parts are illustrated. Spot welding is used extensively in America but sparingly in the United Kingdom. Adhesive bonding with Metlbond on some B-36 assemblies in America was cited and with Redux or Araldite resins in the United Kingdom.

C. E. Nelson

Spark Deposition

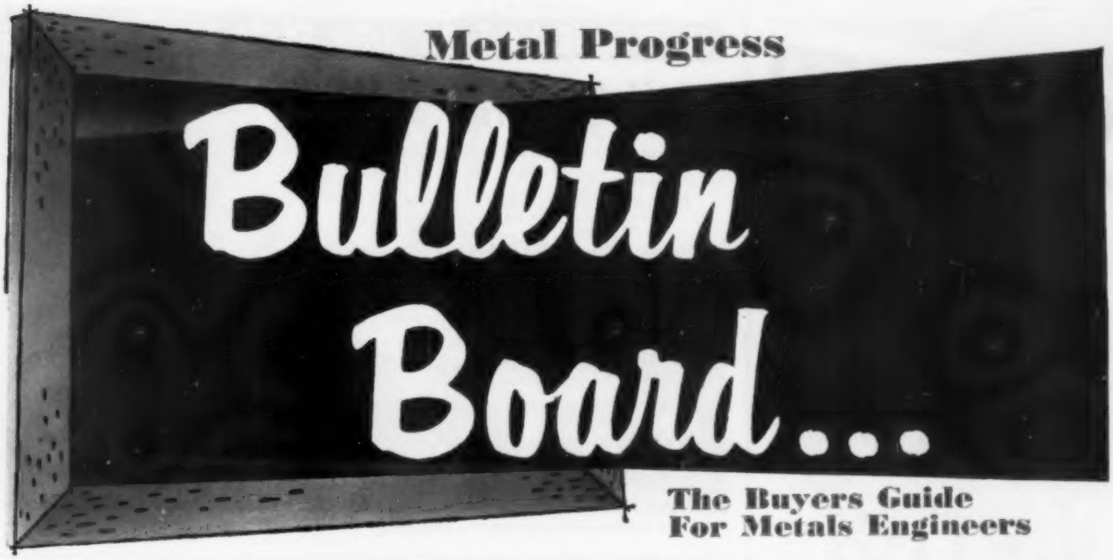
Digest of "And Now, Spark Deposition!", *Metalworking Production*, Vol. 102, March 28, 1958, p. 554-555.

The machining of many of the newer materials, particularly those developed for high-temperature applications, requires that the qualities of several types of cutting tools be combined into one. The Nimonics, for example, require tools with the wear resistance and hardness of carbides plus the toughness of high speed steels.

A recent machine developed by Impregnated Diamond Products Ltd., Gloucester, England, produces the desired combination of qualities. This machine utilizes the transfer phenomenon that takes place in spark erosion to deposit tungsten carbide on the wear surface of tool materials. The process is essentially as follows:

The tool is ground, degreased and set in a tool holder. An electrode of the desired material is positioned in close proximity to the tool and the current is turned on. A spark discharge takes place across the air gap and the electrode traverses the area to be surfaced. This results in a deposit of the electrode material on the tool surface which is harder than the base metal. At the same time, further hardening of the tool surface takes place. This treatment is normally applied to the surface which is subject to the greatest wear, although other surfaces may also be treated if desired. Tools thus treated exhibit a substantial increase in service life.

B. Trock



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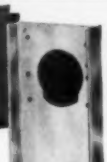

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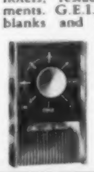

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New Welding Processes

Digest of "Prediction in New Metal Joining Processes", by John J. Chyle. Paper presented at the Society of Automotive Engineers National Aeronautical Meeting, New York, March 31, 1959.

In a tabulation of metal joining processes other than mechanical joints or adhesive bonding, the author lists 15 kinds of pressure welding, 12 kinds of fusion welding and 10 methods of brazing, plus 20 variants related to heat source or protective atmosphere, a total of 57. Some of them of course are not new; others have been described at more or less length in recent issues of *Metal Progress.*

Pressure Welding – For example, for ultrasonic welding, see J. Byron Jones, *Metal Progress,* April 1958, p. 68. Mr. Chyle notes its present limitations to spot or seam welds in foil or thin sheet ($\pm$ 0.10 in.) but believes thicker material can be handled.

In high-frequency resistance welding (W. C. Rudd, *Metal Progress,* May 1958, p. 82), 100,000-cycle current is so directed as to concentrate heat at the very bottom of a sharp "V" where the edges of the joint slightly diverge. It is very fast and the heat-affected zone is of minimum volume.

Foil seam welding is for butt welding flat sheet. As the joint moves between rotating disk electrodes, thin ribbons of the same metal are also fed on top and bottom. Fusion starts at the middle of the plates some distance ahead of the center of pressure, rapidly extends to the surfaces and incorporates the foil or ribbon. The squeeze between electrodes is sufficient to pressure-weld the foil into a smooth surface, smooth enough so it seldom needs subsequent finishing. To this advantage is added dimensional uniformity and high speed (24 in. per min. on 0.087 in. sheet).

An improvement in resistance welding uses magnetic forces to synchronize accurately the pressure and welding current in, say, a spot welder. So time is reduced to as low as half a cycle, and is especially adaptable to metals of high conductivity.

Friction welding was described by Arthur Tesmen in his article on

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Welding . . .

Russian developments in *Metal Progress* for January 1959 (p. 79). Mr. Chyle notes it is limited to cylindrical parts, but it apparently requires comparatively little power.

In thermopressure welding and diffusion bonding, cleaned flat surfaces are pressed together at moderate heat long enough for transfer of atoms across the interface and the formation of new crystals or intermetallic compounds (if the parts being joined are dissimilar). Pressures may run up to 10,000 psi., temperatures are generally below 1000° F. and times may range from 20 min. to 3 hr. The low temperatures may not alter properties acquired by previous heat treatments; distortion also is prevented.

Fusion Welding – The electroslag process was described in Mr. Tesmen's article cited above. Mr. Chyle lists as an important advantage the high rate of metal deposition – as high as 45 lb. per hr. – and mentions as disadvantages the large heat-affected areas adjoining the weld and the coarse columnar crystals in the weld itself. Its future seems to be in joining very thick plates and building up massive layers on large surface.

Electron beam welding (see *Metal Progress*, May 1958, p. 65) uses an electron beam to melt adjoining metals with or without filler wire and is possible only in very high vacuums – below 2×10^{-4} mm. of Hg – not contaminated from any impurities in any electrode. It is also confined to assemblages small enough to be placed in available vacuum chambers.

Arc plasma is somewhat similar to the above. An umbrella-shaped arc is struck between a central electrode and a surrounding nozzle – both water cooled – and argon or helium forced through the annulus. The heat of the arc dissociates the gas molecules into ionized atoms and a stream of this "plasma" at 10,000 to 30,000° F. issues from the torch. This temperature is high enough to serve as a welding blowpipe for the most refractory metals and even to spray-coat refractory oxides.

Brazing – Mr. Chyle confined most of his remarks on this subdivision to the methods used for making sandwich constructions for the aircraft and missile industry. For details of this see *Metal Progress*, October 1958, p. 110. Many variants exist in the nature of brazing compounds and in the methods of heating. The latter may vary from conduction from heated dies, heating in suitable envelope prior to pressure in a separate furnace, radiant energy from high-intensity quartz lamps, and brazing metals incorporated in exothermic compounds or mixtures. The author believes there is a large future ahead for this process in all parts where a combination of strength, rigidity and light weight is desirable.

E. E. T.

Low-Temperature Transverse Impact Test

Digest of "Effect of Phosphorus and Sulphur Content on Ductility and Toughness of Cast Low-Alloy Steels", by John Zotos. Paper presented at the A.I.M.E. Electric Furnace Conference, Detroit, December, 1958.

A study of the data indicates that the ductility and impact resistance of the steel tested were definitely improved by reduced sulphur and that for the best results the maximum sulphur should be 0.010%. It is difficult to reach the same conclu-

Tool Steel Topics

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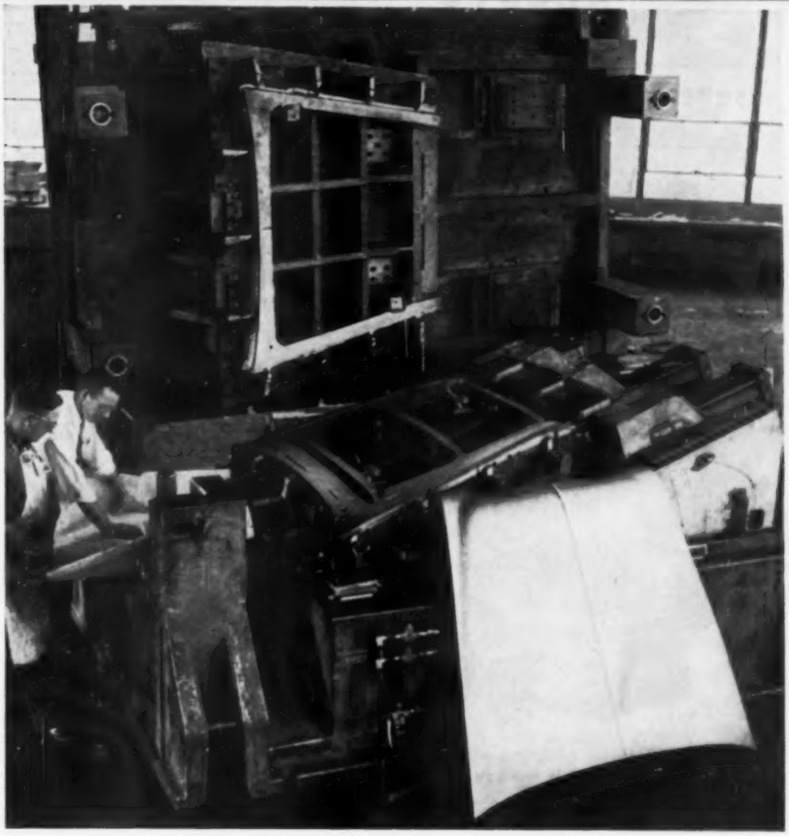

Automotive Die, in 101 Sections, Made from Water-Hardening Steel

This huge die, made up of Bethlehem W-1 carbon water-hardening tool steel, trims an automobile hood. Made from tool steel furnished by Peninsular Steel Co., Detroit, the die was photographed recently at Republic Die & Tool Company, Wayne, Mich. It contains 44 composite sections, 34 wear plates, and 23 solid sections.

Bethlehem carbon water-hardening steels were selected for this exacting application because of their good wear-resistance, easy machinability, and simple heat-treatment—plus ease of welding should repair become necessary.

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Here's How to Stabilize Gages

High-precision gages, commonly made of BTR tool steel (AISI Type 01), need a stabilization treatment if they are to maintain their accuracy for years. Otherwise expansion will eventually change dimensions outside of the permissible tolerance. These dimensional changes are in a magnitude of hundred-thousandths of an inch per inch, or smaller. Insignificant on ordinary tooling, they are important on precision gages.

The expansion which occurs over a period of time is due to the transformation of austenite retained during the quench for hardening. The object of the stabilization treatments is to transform the retained austenite during the treatment, so that none remains which could transform later on. This condition exists in all tool steel grades which can be hardened to Rockwell C 60 or higher.

The most common method for stabilizing high-precision BTR gages is: 1. Quench and temper in the normal manner to produce the desired hardness. 2. Rough grind. 3. Subzero cool to minus 100/120 F in refrigerator or dry ice. 4. Warm to room temperature and then retemper at original temperature. 5. Finish grind to size. 6. Repeat cycles of subzero cool followed by tempering five more times. 7. Lap or superfinish to size.

Sometimes it is possible to shorten this procedure, particularly if the design is such that there is little hazard of cracking. For example, the tools can be subzero cooled directly from the quench, with no interval at room temperature, followed by tempering and grinding. This will permit stabilization with only two additional cycles of subzero cool plus temper, but the disadvantage is that cracking may occur after quenching.

It is also possible to shorten the stabilization by cooling to minus 314 F in liquid air. This permits reducing the cycles of subzero cool plus temper to three instead of six.

Impact Test . . .

sion for phosphorus. The effect of the type of sulphide or the residual oxygen on the low-temperature transverse impact properties is not discussed. For best results every possible step should be taken to avoid Type II sulphides in the intercrystalline as-cast grain boundaries.

We reached the same conclusion a long time ago, while producing ingots for British gun forgings. To achieve maximum low-temperature transverse impact results, we not only had to keep the sulphur below 0.010%, but avoid the use of aluminum for grain size control, because of the degree of deoxidation promoted by aluminum and its effect on the type of sulphide in the ingots. This was probably aggravated by the large ingots cast and would not have nearly as much effect in the castings turned out by the usual steel foundry. In my opinion some interesting research could be carried out to determine accurately the effect of residual oxygen content of a heat of steel on the sulphide type and low-temperature toughness and ductility of the final casting. I believe that a comparison of silicon-killed acid and basic cast structures with aluminum-killed (fine-grained) acid and basic castings would produce interesting results.

The value of the impact test for comparing some basic properties in heats of high-strength steels is again demonstrated. Perhaps we should develop this test to encourage its use, universally, for appraising such steels.

With a routine calcium carbide-type slag and given arc furnace practice, it took hours to complete a reaction which, as demonstrated by Perrine and others, should require only a few seconds to complete under perfect conditions. This reaction time is extended because, under the conditions usually existing in the arc furnace with a proper alkaline slag, the sulphur is removed almost instantaneously at the contact surface between slag and bath; much time is required to obtain the diffusion of the sulphur at all points in the relatively deep and dead bath of steel to the point of high chemical activity at the slag line. To remove sulphur quickly from a steel bath by means of a surface slag, some means

Impact Test . . .

of reducing the diffusion time is needed. This calls for a turbulent bath of the proper temperature. Such a development might lead to a rotating kiln type of furnace with the bath consisting of a mere sheet of highly turbulent metal which is carried through the kiln at high speed under a thin layer of slag held in contact with the bath by centrifugal action.

This points the way for some real development in steelmaking and with the work of Perrine always in mind we should perhaps build special equipment to provide greatly increased contact of slag and highly turbulent fluid metal so that the sulphur is reduced as close as possible to zero before the steel is added to the arc furnace.

Work has already been done in this area and if the thinking applied to the sulphur reaction is directed to all the steel bath reactions, it should be easy to develop a procedure that will go all the way with hot metal as the major charge used in the electric furnace or openhearth furnace.

This well-written paper by Mr. Zotos provides some interesting data which should serve as a good guide to anyone interested in the development of high-strength steel in any form with especially good ductility and toughness as indicated by the low-temperature transverse impact test.

H. W. McQuaid

Fabrication of Molybdenum Sheet

Digest of "The Development of Refractory Sheet Metal Structures", by Alan V. Levy and Saul E. Bramer. Paper presented before the Society of Automotive Engineers National Aeronautical Meeting, New York, March 31, 1959.

THIS DOCUMENT is a rather complete description of methods used by Marquardt Aircraft Co. to make such things as nose cones, tubes, cups and brackets from molybdenum sheet. (The usual alloy contains 0.5% Ti; its properties have been described in *Metal Progress*, June 1956, p. 72, and July 1956, p. 103). Although the alloy is formed while hot, its strength in service is due primarily to prior "cold" work, so fabrication temperatures must not cause recrystallization – that is, must be less than 2300° F. Articles made from it are suitable for low-load, short-time, high-temperature (2400 to 3000° F.) service, such as atmospheric re-entry of missiles at hypersonic speeds.

The authors report their experiences with over 60 heats of sheet in 0.01 to 0.08-in. gages, and sizes up to 36 × 60 in. Physical properties, chemical analysis, flatness (after surface grinding 0.003 in.), formability and weldability have markedly improved in uniformity. Other characteristics of the sheet now available are not so favorable.

Transition temperature is 300 to 500° F., and that means the sheet is very brittle at room temperature. Cracks often occur during normal handling. Surface grinding helps.

Sometimes a sheet is so badly laminated that it is actually separated into two sheets over large areas. This is due to the present limitations in the rolling mills; temperature is below 2300° F., less than half the melting point, and this introduces large shear stresses along the flat grain boundaries. It is possible that this will be corrected if hot mill equipment can be built for rolling at much higher temperatures.

Now and then a heat of sheet is

Molybdenum Sheet . . .

encountered with an unfortunate habit of splitting at 45° to its rolling direction at any scratch or notch. The only known remedy is to avoid all such stress concentrations.

Since the properties at service temperatures depend upon the recrystallization temperature of the sheet, the latter should be held to narrower limits. At present, this varies within the range of 2200 to 2450° F., depending on processing variables in the sheet mill.

Forming – Much of the paper under review describes the author's experiences in the forming and joining of the 0.5 Ti alloy sheet, and the original document should be consulted for details. Shearing or sawing is done after preheating to 700° F. ("Tempilstick" control). Forming by a variety of processes, such as spinning, stamping, "floturning", stretch forming, is done on hot sheet; proper working temperatures vary with thickness, ranging from 600° F. for 0.020-in. sheet to 2200° F. for 0.320-in. The authors apparently favor hot headed mechanical fasteners; rivets are heated to 1100° F. and the parts being joined are heated above their transition temperature to avoid cracking. While welding, either by resistance (spot) or fusion, is possible it requires very precise equipment and unusually close control.

Coatings – Many protective coatings have been tested in the Marquardt laboratories, and the authors believe that "Chromalloy W-2" is the best. The completed molybdenum part is packed in a proprietary powder in a sealed retort and heated to 2000° F. several hours, during which a case about 0.002 in. thick forms on all surfaces by processes similar to cementation. The

final surface is as smooth as the original; "throwing power" is excellent (even under rivet heads), reproducibility is good and the coating resists thermal shock. Samples under tension were heated to 3000° F. for 90 min. before oxide vapors became visible.

E.E.T.

Continuous Casting

Digest of "The Rational Design of a Mould for the Continuous Casting of Steel", by G. I. Kozlitin and L. N. Kolybalov, *Stal*, Vol. 3, 1957, p. 209-213.

THE PAPER DISCUSSES in detail the construction and operation of three types of machines for the semicontinuous casting of stainless steels. In particular, it discusses a reciprocating mold-type machine which is cheaper to operate than the standard stationary and spring-loaded types. This article is indicative of the very wide interest taken in Russia in continuous casting of steels.

One of their most important advances has been the successful continuous casting of large tonnages of rimming steels after vacuum degassing at about 30 mm. pressure.

The first installation described is the stationary mold machine at the Red October works. The ingot or billet is removed by a crosshead running on two vertical screws driven by a 9-kw. electric motor. The speed of withdrawal may be varied from 0 to 6 in. per min., and billets of 0.6 × 2.5-in. cross section and about 7 ft. long are produced. The duration of casting a billet of the above size at a speed of 4 in. per min. is about 20 min. Babcock & Wilcox Co. have experimented with a similar unit.

In this process, however, where the solidifying billet moves in relation to the mold surface and at a speed of removal of 4 in. per min., the solidified rim of metal near the top of the billet only has a thickness of about 0.2 in. If the frictional force between the solidified rim of the billet and mold is increased due to poor lubrication, this crust is easily broken and defects occur in the billet surface. When a major break occurs, it can be repaired only after stopping the machine.

Since 1951, a series of improvements have been carried out on this

Continuous Casting . . .

type of casting machine. The mold has been set on four spiral springs which contract in relation to the frictional forces between the mold and billet surface. In this instance, the springs are so selected that an increase in the frictional force will not result in fissuring of the billet, but will cause a downward movement of the mold at about the same speed as the billet, thus releasing the tensional forces on the billet. This type of machine is in operation on two experimental machines in the United Kingdom.

The greatest improvement was found in a machine designed so that there was no relative movement between the mold and billet during casting. At the end of the downward movement of the mold (a displacement of 2 in.), the mold returned to its original position three times as fast. However enough time is allowed during the 2-in. movement to allow a thick layer of solid steel to form, and thus any defects which may form are limited to small laps and occur when the mold returns quickly to its original position. This reciprocating motion is controlled by a cam mechanism and requires no more power than the original stationary mold. The advantages claimed are that the reciprocal motion of the mold is effective in preventing defects in the billet and lends itself to fully automatically controlled continuous casting.

W. A. MORGAN

Present Status of Nuclear Power

Digest of "Current Nuclear Power Developments and Their Outlook", by Karl P. Cohen. Paper presented to Energy Resources Conference, Denver, Colo., Oct. 16, 1958.

THE ROSY HOPES that many atomic-electric power stations would be promptly built – so widely held by industrialists throughout the world a few years ago – have been replaced by the sober realization that such plants are quite expensive and much is yet to be learned about their economical design and operation. Nevertheless, enough is now known so that firm prices and appropriate performance guarantees can be had from responsible manufacturers for 200,000-kw. central stations to operate in 1963 as outlined in the table below:

	CONVENTIONAL COAL-FIRED	NUCLEAR FISSION
First cost, per kw.	\$135 to 185	\$300 to 350
Operating costs, mills per kw-hr. (70% load factor)		
Capital charges	3.1 to 4.2	6.8 to 8.0
Operation	0.6	0.7
Fuel	2.0 to 3.5	3.0 to 4.0
Total	4.7 to 8.3	10.5 to 12.7

It is rather remarkable that the top of the range for conventional fuel plants (8.3 mills per kw-hr.) is so close to the low figure (10.5) for nuclear power plants. It indicates that this gap can be bridged by manufacturing economies when an increased number of plants can be built; by decreased engineering

Nuclear Power . . .

charges as more information is gained; by discovering the best combination of fissionable material, coolant, and auxiliary equipment – superheaters, for example; and by less extravagant design as we know more about the capabilities of the equipment and its parts. (For example, General Electric's Vallecitos boiling water reactor was designed for maximum thermal output of 20,000 kw.; it is operating at 30,000 and undoubtedly can produce safely and continuously 40,000 kw. of heat or more.)

"The prospects are therefore excellent that nuclear power stations using fissionable fuel will be operating as sound commercial propositions in the United States – in high cost fuel areas by 1965, and quite generally in 1970." Edward Teller, the principal American spokesman, suggests A.D. 2000 as a reasonable date for achieving commercial power from the fusion reaction.

In general terms, the existing British program is based on gas-cooled, natural uranium, graphite-moderated. This removes dependence on enormously expensive plants for isotope separation and enriched fuel, but involves many operating difficulties since natural uranium is so unstable under high heat and radiation. Consequently, the new plants in the British program are to use enriched uranium, thus approaching the American stream of development centered on water cooled, water-moderated, enriched uranium.

Such pressurized power systems are even now approaching the status of standard propulsion for U.S. Naval vessels, and the economic gap between floating power plants of the two varieties (fossil fuel versus atomic) is no greater than that quoted at the outset for stationary ones.

"The Soviet reactor development program disclosed in 1955 resembled our own in many ways. They have about 2,000,000 kw. of water cooled nuclear power plants under construction, roughly half graphite-moderated, and half water-moderated. They are using enriched uranium as fuel and are trending away from metal towards oxide fuels. They are planning reactor experi-

Nuclear Power . . .

ments with sodium cooled, homogeneous and other reactor types on quite an impressive scale; their idea of a reactor 'experiment' appears to be one generating about 50,000 kw. The Russians at Geneva exhibited models of reactors which were not described in their speeches, and vice versa. One might conclude from this haziness about the details that they are revising their program."

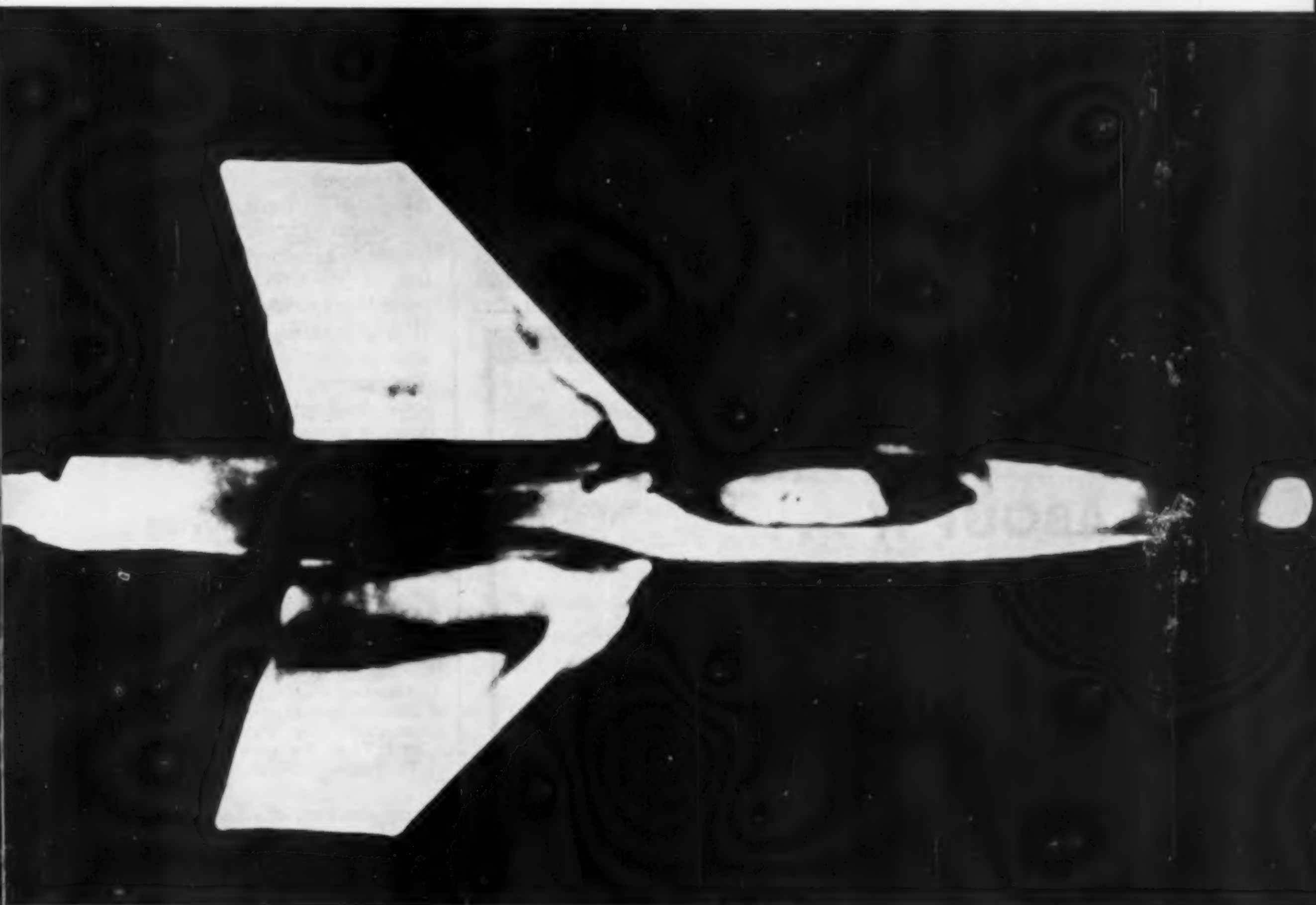
While a promising civilian application is process heat, fresh water from salt by distillation rather than by ion exchange or other separation processes is not a reasonable idea. To make the desert bloom as a rose would require water costing no more than 5 to 10¢ per 1000 gal. Cities could pay ten times as much for domestic use. This may well be within the range of possibilities of nuclear energy. E.E.T.

Evaluation of Stresses at High Temperature

Digest of "A Machine for the Evaluation of High-Temperature Alloys Under Combined Static and Dynamic Stresses", by P. E. Hawks and C. H. Ek. Paper presented at the Annual Meeting of the American Society for Testing Materials, Boston, June 1958.

Many materials are subject to combined static and dynamic stresses at high temperatures (for example, gas turbine buckets). General Motors Corp. has built a number of machines to evaluate alloys for operation under these conditions. The machines can apply static stresses up to 85,000 psi. simultaneously, with cyclic flexural stresses to 45,000 psi. using ¼-in. diameter specimens. Frequency of flexural stress application, 450 to 650 cycles per sec., is of the same order of magnitude as that encountered in service.

Static loading is applied through a dead-weight lever arm system. Dynamic flexural stresses are applied through an electromagnet and regenerative feedback system which gives resonant vibration in an elastic system composed of the specimen and the axial loading assembly. The specimen is heated by an atmospheric air-acetylene torch with tem-



Stress Evaluation . . .

perature control within ±5° F.

Computation of flexural stresses in an axially loaded beam of varying section and varying temperature (and therefore elastic modulus) over the length is complex and was performed on a digital computer. Once the computer has been properly programed, calibration can be performed quickly for a variety of axial loads, specimen materials, elastic moduli, and variations in modulus with temperature. Flexural stress at the critical section can then be obtained as a function of flexural deflection at any convenient point.

Tests were performed on Allegheny-Ludlum alloy A 286 at 1100° F. and General Motors alloy GMR 235 D at 1800° F. A constant static stress level (a percentage of the 100-hr. stress-rupture value) was maintained with varying fatigue stress levels giving failure times to 100 hr.

These tests indicate relatively little loss in allowable dynamic stress component as the static stress component is increased to a high fraction of the 100-hr. stress-rupture value. At low static stresses, that is, at approximately conventional fatigue testing conditions, the S-N diagrams are nearly horizontal at lower temperatures with slope increasing as temperature is increased.

C. O. Smith

Effect of Alloying Elements on Hydrogen in Steel

Digest of "The Influence of Alloying Elements on Hydrogen Content and Hydrogen Diffusion in Steel", by Yu A. Klyachko and T. A. Izmanova, *Stal*, Vol. 17, No. 6, 1957, p. 507.

THE ADDITION of alloying elements to iron and steel affects the diffusion of hydrogen and solubility in the solid alloy. The complete removal or "fixing" of hydrogen in large forgings or castings, and its diffusion during pickling processes, is important in preventing cracking or embrittlement. The authors have therefore studied the solubility and rate of diffusion of hydrogen in binary and ternary alloys of iron.

The experimental alloys were

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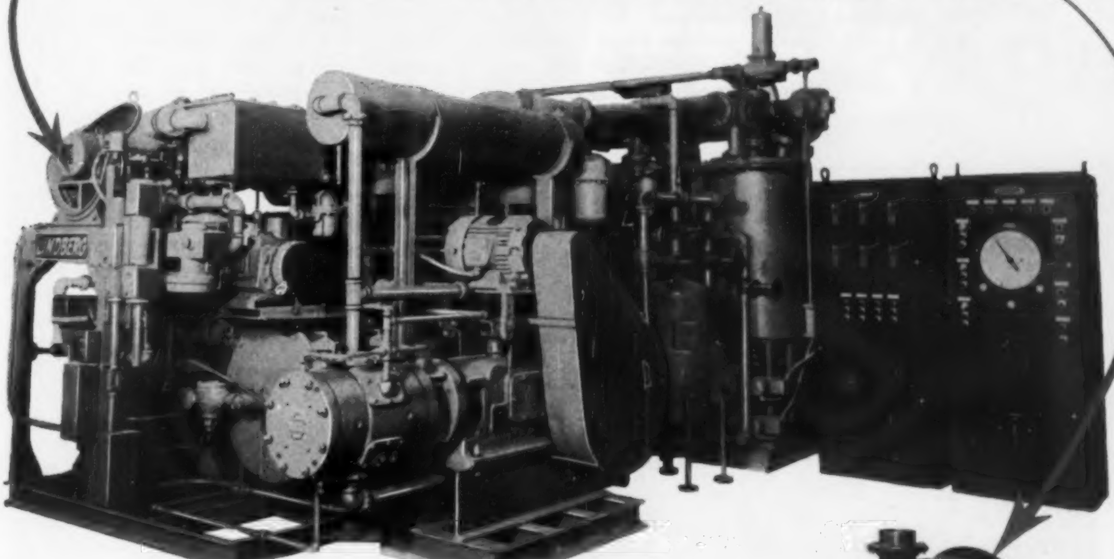

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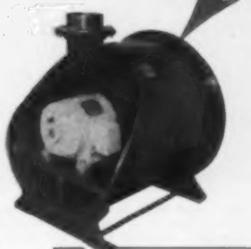

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Hydrogen in Steel . . .

melted in a high-frequency induction furnace under a basic slag. The base material was Armco iron, and calcium was used as the deoxidizer. Alloys of the following types and composition ranges were produced:

1. Fe-C (0.025 to 2.64 C)
2. Fe-Si-C (0.97 to 4.32 Si, 0.035 to 0.50 C, 0.12 to 0.14 Mn)
3. Fe-Mn-C (0.76 to 14.4 Mn, 0.035 to 0.96 C, 0.10 Si)
4. Fe-Zr-C (0.13 to 1.48 Zr, 0.03 to 0.45 C)
5. Fe-Ti-C (0.10 to 3.90 Ti, 0.03 to 1.15 C, 0.1 Si, 0.1 Mn)

The alloys were tested in the forged and cast and quenched condition. Two ingot molds were used. A bottom-pour type produced an ingot which could be tested immediately for hydrogen content by vacuum fusion. An ingot formed in a "big-end-up" type was put into a special container so that it could be immersed in mercury for a month or more. This latter ingot was then forged to 15/32-in. diameter rods, machined to ⅜ in. and then cut into ⅜-in. long specimens. Hydrogen was determined by vacuum fusion.

In the experiments in which the ingots were kept under mercury at room temperature, the quantity of hydrogen liberated was measured each day. The results for all of the systems show that the rate of hydrogen liberation is at first rapid but after about five days levels off. Results are given for the Fe-Ti-C alloys which show that with increase in the titanium content the amount of hydrogen absorbed during melting is increased. For the same carbon content, an increase in titanium also decreases the rate of liberation of hydrogen. However, in comparing a high-titanium low-carbon alloy (3.90% Ti, 0.035% C) with a low-titanium high-carbon alloy (0.10% Ti, 1.15% C), the high-carbon alloy has a much slower rate of gas evolution, that is, the carbon content seems to be more effective in slowing up hydrogen elimination than the titanium content. For the other compositions, it was shown that as the content of the alloying elements increases, the mobility of hydrogen at room temperature decreases. Listed in order of decreasing effect, these elements are zirconium, titanium, carbon, manganese and silicon.

The hydrogen remaining after prolonged holding was determined by "big-end-up" test ingots at 1560° F. These tests confirmed that vacuum heating released only slightly more hydrogen than diffuses out at room temperature. Hydrogen in the as-forged and in the as-cast specimens was determined by vacuum fusion. The as-forged metal contained considerably less hydrogen than the as-cast alloy although the variation of hydrogen content with composition was similar.

The results of this work show that alloying elements increase the solubility of hydrogen in steel and in no instance decreases it. Some of the elements do this by the formation of stable hydrides. They may also promote the formation of austenite or martensite. Titanium and zirconium, and surprisingly carbon, can be classed as hydride-forming elements. All the elements studied lowered the mobility of hydrogen in iron alloys.

W. A. Morgan

Effects of Mechanical Working on Inclusion Deformation

Digest of "Some Effects of Mechanical Working on the Deformation of Non-Metallic Inclusions", by F. B. Pickering, *Journal*, Iron and Steel Institute, Vol. 189, June 1958, p. 148-159.

THE TYPE AND DISPERSION of non-metallic inclusions are known to have important effects on the mechanical properties of steels, in particular, fatigue properties, transverse ductility, and impact behaviour. Many studies have been made of the inclusions present in steel ingots. However, this paper describes one of the first attempts to determine what happens to these inclusions during subsequent hot working.

Experimental iron-oxygen-silicon alloys containing inclusions of iron oxide, inclusions of the important silicate group, and duplex oxide-silicate types were examined. The effects of a range of rolling reductions and temperatures on the inclusions were investigated by metallographic methods. The results can be explained if it is assumed that the deformation of the inclusions is due to the forces at the inclusion-metal interface. These will increase with decreasing rolling temperature and increasing rolling reduction. On the other hand, the inclusion will become less plastic with decreasing rolling temperature. It will then be more likely to fracture.

At high rolling temperatures and small reductions, massive silicates are deformed into ellipsoidal masses. In duplex inclusions, the more plastic phase may be squeezed to the ends of the less plastic phase. At lower temperatures, fracture occurs at various stages of deformation; this disperses the inclusion. Dispersion of duplex inclusions may be assisted by fracture along the interface between the two phases. At still lower temperatures, the inclusions are even less deformable and the fracturing forces are greater. They may then be broken up into stringers elongated in the direction of rolling.

The stage of reduction at which fragmentation occurs has an important influence. If it occurs early, the

(*Continued on p.* 198)

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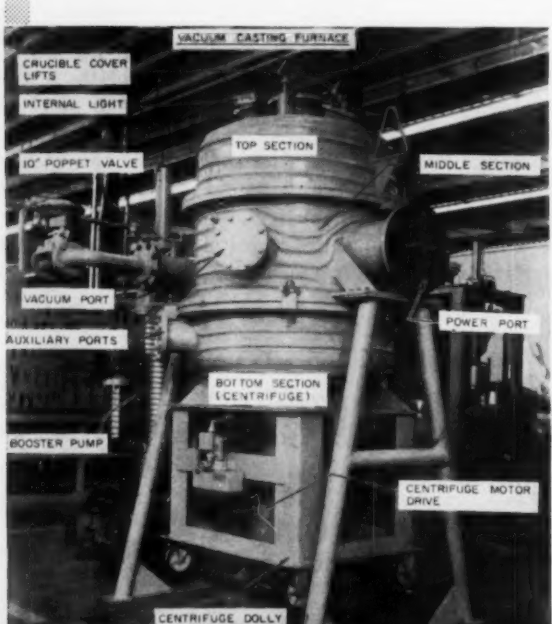
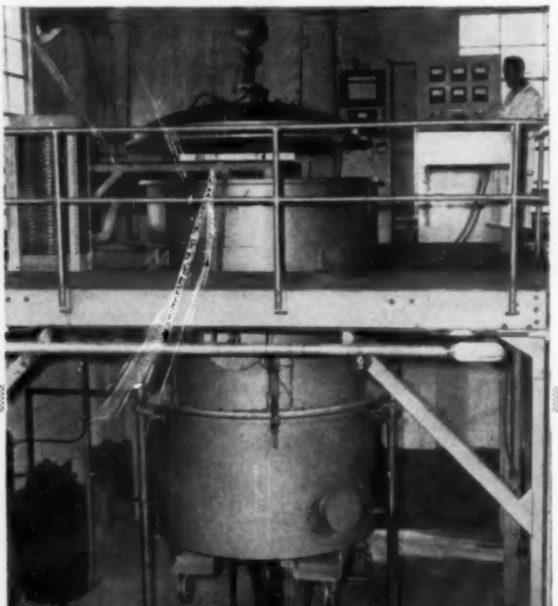


Radioactive materials handling investigations are safely carried out with this Stokes prototype vacuum furnace. It is remotely operated by manipulators and other external controls. This installation represents another specific requirement met through Stokes flexibility.



Uranium melting on a production basis is accomplished by this Stokes induction melting furnace. Designed for safety and convenience, the furnace is serviced from the top and features a removable bottom section to facilitate handling of poured materials. It is typical of Stokes inherent flexibility.

Inclusions . . .

dispersed fragments are deformed and a second fracturing process may even occur. If it occurs late, the fragments may develop a characteristic fish-tail form at their ends. This is attributed to the large forces at the metal-inclusion interface causing preferential deformation of the outer layers. If it occurs very late, clean fractures may still be present. In extreme instances, the matrix may not fill in completely between the fragments, leaving unwelded voids. Extensive craze cracking may also be present in the larger inclusions.

It appears essential, if large injurious silicates are to be converted into less harmless dispersion, to promote early fracture into many fragments. Initial working at low temperatures would encourage this. Working at high temperatures may then be desirable to improve the form of the fragments. Multiple cold working with intermediate reheating would be better than all working in one stage. L. E. SAMUELS

Hot Cracking in Welds

Digest of "The Mechanism and Origin of Solidification Cracking in Welds", by I. I. Frumin, *Avtomaticheskaya Svarka*, No. 1, 1957, p. 88-102.

IN WELDING, one of the most feared defects is hot cracking. The direction of hot cracking generally is in the direction of growth of the columnar crystals. A root opening is a region of poor thermal conductivity and therefore is the origin of hot cracks in many instances. The tendency toward cracking increases with decrease in shape coefficient, which is the ratio of width of bead to depth of penetration. Pear-shaped welds are particularly prone to cracking. This paper is a dilatometric study of hot cracking in the submerged-arc welding of mild and alloy steels. The weld metal undergoes expansion and contraction immediately after it solidifies.

The deformations measured at a tangent to the edge of the weld puddle are significant for cracking. These deformations were measured by a sensitive extensometer so located that its two points were located on the same drag line or solidification ripple. A bare Pt-PtRh thermocouple (0.001-in. wires) was embedded in the weld between the points. The extensometer points were 0.08-in. tungsten rods sharpened to a 60° cone. Welding proceeded for 1 min. before the extensometer points were immersed back of the arc, and continued for 1 min. thereafter. Oscillograms of the thermocouple output were taken as well as motion pictures (one frame per second) through the eyepiece of the measuring microscope. The two extensometer points were ¾ in. apart, and freezing, of course, started simultaneously at the two points. Preliminary tests in which the extensometer points were immersed in the slag but not in the weld metal indicated a very slight contraction during freezing.

The first tests were made in mild steel at room temperature, using a high-manganese flux, 720 amp., 36 v., 10 in. per min. travel speed. The steel was 1⅝ in. thick, 8 in. wide.

(*Continued on p.* 202)

Hot Cracking . . .

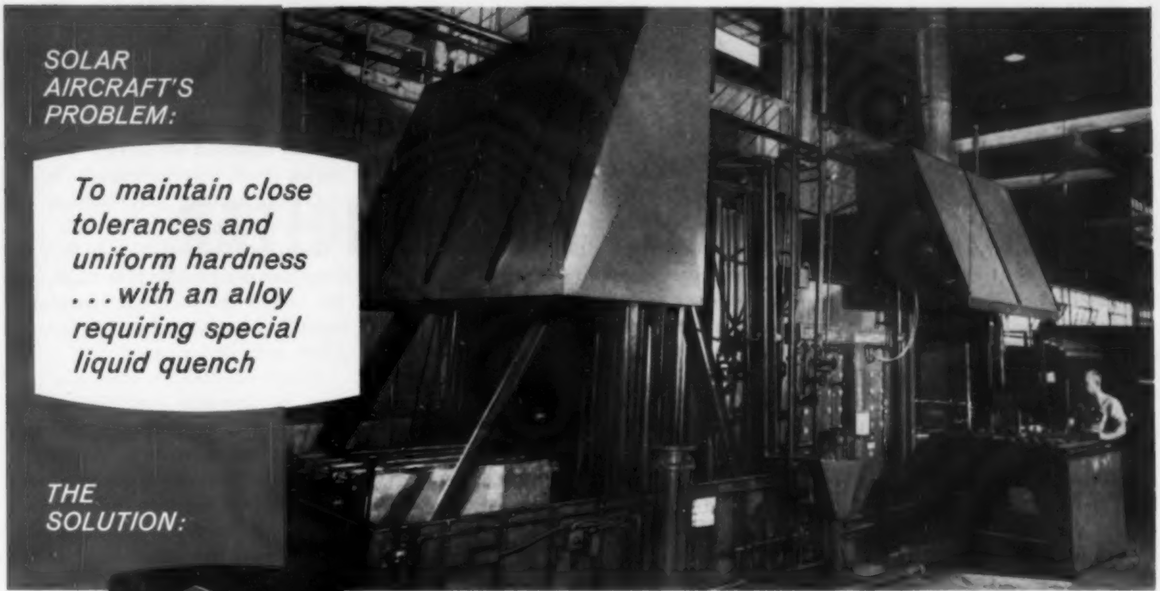
During the first 6 sec., the extensometer recorded no change. From 7 to 10 sec. an elongation of 0.15% was recorded. During this period the temperature was 1510 to 1480° C. (2750 to 2695° F.) and the cooling rate was 37.5° C. (99.5° F.) per sec. From 10 to 15 sec., there was sudden contraction to −0.45%, beyond which little further contraction occurred. The same type of result was secured with higher carbon and Cr-V steels.

To determine the temperature at the initiation of a hot crack, bars of steel (0.22 C, 0.31 Mn, 0.034 S) 4¾ in. square, 24 in. long, were cut in two so that a gap of 0.06 in. wide extended across the path of the arc. The extensometer points straddled the crack caused by the gap. Instead of elongation reaching a maximum and being followed by contraction, elongation continued throughout the cooling, reaching 4½% in 60 sec. In five tests the temperature at which the crack occurred varied from 1300 to 1390° C. (2370 to 2535° F.). With the Cr-V steel there was 0.25% elongation at 11 sec. Contraction then occurred until 16 sec., at which time the temperature was 1130° C. (2065° F.) and a crack started. Elongation resumed at once and continued during further cooling.

Preheating the Cr-V steel to 380° C. (715° F.) not only prevented cracking but eliminated the expansion period. The cooling rate during freezing was 10° C. (50° F.) per sec. and no change in length occurred until 14 sec., by which time the weld had cooled to 1150° C. (2100° F.). Slow contraction then set in, amounting to −0.4% at 50 sec. Similar results were obtained with the low-carbon steel preheated to 400° C. (750° F.). Preheat alters the character of the deformation during and just after freezing.

The results show that hot cracking occurs during the liquid-solid transition in the bead containing grain-boundary liquid under deformation arising from nonuniform heating. Without preheat and when cracking does not occur, elongation precedes contraction. Not over 0.5% elongation was observed in any test, and this can be accommodated by any metal free from hot shortness.

D. L. CHURCHILL



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Shot-Peening

Digest of "Shot-Peening in Relation to Gear Tooth Scoring", by John C. Straub. Paper presented at the annual meeting of the American Society of Lubrication Engineers, Cleveland, April 24, 1958.

GEAR TOOTH failures are of three types: tooth breakage, pitting, and scoring. Tooth breakage, due to fatigue, is of course catastrophic. Pitting, while it is a less disastrous condition caused by high contact stresses, is also believed due to fatigue. Scoring, like pitting, is a surface condition, but it is not related to fatigue. It may occur early in the gear's use, and is caused by a welding of tooth surfaces, rather like the seizure of a journal and bearing.

Gear design does not always permit a simultaneous solution to all three types of failure. For example, to reduce a tendency to scoring, a lower sliding velocity at the tooth surface is desirable. This may be achieved by reducing the pitch of the gear, but this leads to a greater stress on the teeth and so encourages failure by fatigue. So, an increase in the endurance limit permits greater flexibility of design, and gear tooth scoring is minimized. Actually, peening has no direct relationship to the scoring problem.

Shot-peening has been used to increase the endurance limit of springs for a number of years. Its effectiveness is greatest in long-life, low-stress applications. For instance, the endurance limit of an automotive gear with a life of ten million cycles can be increased 50% by peening. For an expected life of only 100,000 cycles (with correspondingly higher stresses), peening may increase the endurance limit by only 10%.

Peening is effective on both hardened and machinable gear teeth, and the slight increase in roughness caused by peening does not seem to affect gear performance.

Visual examination does not provide an accurate appraisal of the quality of a peening job. Consequently, the efficacy of peening is judged by the curvature produced on a standard test strip that has been peened on one side only, while passing through the same cycle as the work to be assessed. The curvature of the sample offers a semiquantitative indication of peening efficiency, so long as it is combined with some measure of the coverage of the operation. Coverage is defined as the proportion of area that has been impacted during peening.

While a coverage of 98% is said to be "full", experiments show that gears peened for a period several times as long as that required for full coverage display a greater improvement in their endurance limit. Clearly, an economic balance between greatest increase in endurance limit and production efficiency has to be sought.

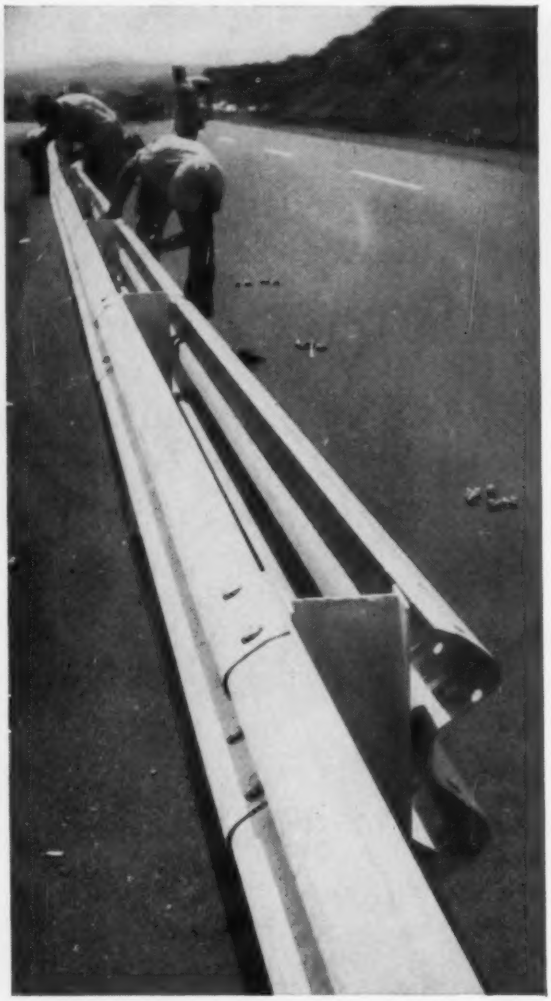
It is important that the shot used in peening is uniform and contains a minimum of broken pieces. The most economical operation is usually obtained by using small uniform shot with a high velocity of impingement. The shot themselevs are chosen for their resistance to breakage rather than for a high hardness value.

J. GORDON PARR

... HEAT-TREATING - 1960 ...
CAMBRIDGE METAL-MESH BELTS are the answer to the big problems you'll face in the competitive '60's—tighter operating costs, higher production and consistent quality.
Continuous movement of products through heat-treating operations, as well as quenching, washing and drying, speeds up production and cuts costly manual handling.
Heat, liquids or gases flow through the belt and around the product for fast, thorough processing... assuring uniformly high quality.
Superior belt design and manufacturing techniques mean longer belt life, fewer repairs, lower operating costs.
Belts can be made heatproof or acidproof—in any mesh, weave, metal or alloy—with any side or surface attachments.
Call your Cambridge Field Engineer now. He'll be glad to discuss any aspect of Cambridge Belts—from manufacture to installation and service. Look in the yellow pages under "Belting, Mechanical". Or, write for FREE 130-PAGE REFERENCE MANUAL.
BELTS
The Cambridge Wire Cloth Co.
Department B • Cambridge 9, Md.
Manufacturers of Wire Cloth, Metal-Mesh Conveyor Belts, Wire Cloth Fabrications

Hot-Dip Galvanizing Replaces Painting

...and Proves A Life Preserver For Highway Life Guards



It is estimated that road building to the extent of six billion dollars will make 1959 the biggest highway construction year since Congress, in 1956, authorized the 41,000 mile interstate highway system.

Last year, as a part of this continuing program, 11 miles of hot-dipped galvanized guard rail were installed on the Pennsylvania Turnpike near Somerset, Pa. The rail was galvanized after fabrication and delivered to the site as needed. Under normal conditions, construction crews installed an average of 3000 feet per day. For complete protection against atmospheric corrosion, galvanized bolts were used to fasten the rails in place. This type of double faced guard rail has become increasingly popular especially on older highways where narrow medial strips are a hazard.

Noteworthy is the proven fact that the ultimate cost of hot-dip galvanizing is lower than painting because it eliminates the recurrent expense of *re-painting.*

Here is an example

The hot-dip galvanized bridge railing shown here was installed on the Merritt Parkway near Milford, Conn. in 1938. *In the ensuing 20 years it has retained its appearance and strength without painting.* This is just one of the many installations where galvanized steel is saving the nation's Highway Departments millions of maintenance dollars every year. Thanks to the protective zinc coating, galvanized highway structurals are immune to atmospheric corrosion and have the added advantages which the inherent strength of steel provides.

ASTM SPECIFICATIONS

Steel products to be galvanized after fabrication, and approved for installation on inter-state highways, are covered by ASTM Spec. A123 and apply to:

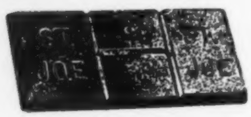
- Bridge Structurals
- Decking and Railing
- Grating
- Fence Posts
- Sign and Reflector Supports
- Expansion Plates
- Rocker Plates
- Guard Rails
- Lighting Standards

NOTE: ASTM Spec. A123 corresponds in most cases to a similar specification of the American Assoc. of State Highway Officials, e.g., ASTM A123 is the same as AASHO Spec. M111-55.

ST. JOSEPH LEAD COMPANY

ST. JOE

250 Park Avenue
New York 17, N. Y.



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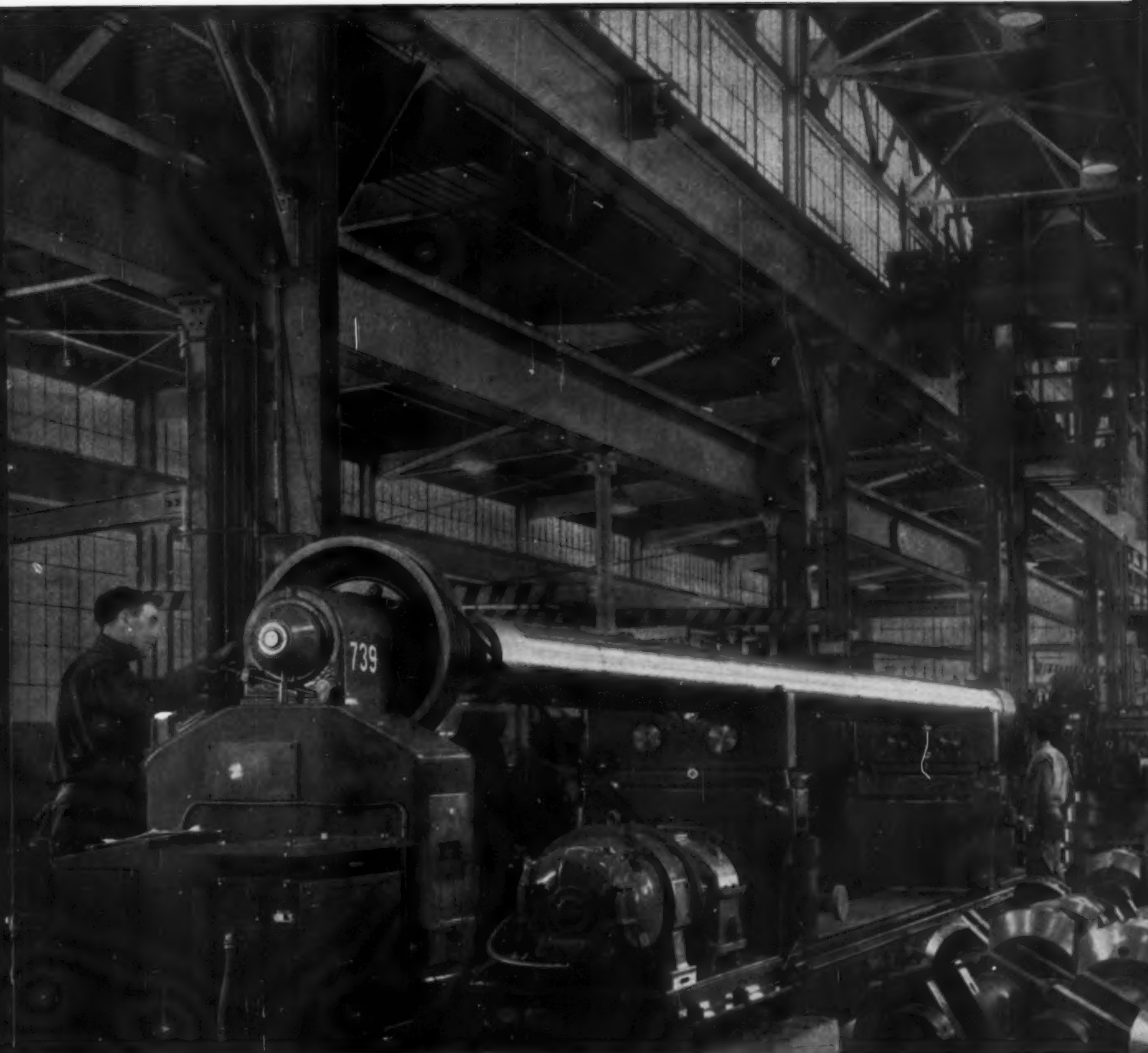
739

Take advantage of a complete line of

NATIONAL ELECTRODES and POWDERS

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Whatever technique you use...whether you are doing quantity runs or special individual tests... there is a "National" spectroscopic product to assure accurate results every time.

NEW GRAPHITE GRADE SPK—offers superior *reproducibility.* A free sample of this high-purity rod will prove this on your tests. Also available in preforms.

GRAPHITE GRADE AGKSP—the accepted industry standard in high-purity electrodes. Available in rods and preforms.

CARBON GRADE L113SP—a high-purity carbon rod for specialized applications.

GRAPHITE POWDERS SP1 AND SP2—used as a diluent and for pellet forming.

These products are manufactured from raw material to finished product in NATIONAL CARBON plants. Exclusive purification methods provide a uniform product from end to end and shipment to shipment. Use "National" spectroscopic products on all your analyses.

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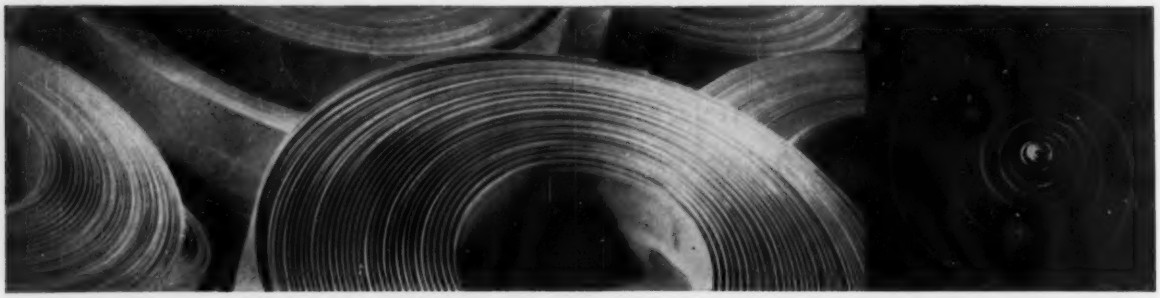
OFFICES: Atlanta, Chicago, Dallas, Houston, Kansas City, Los Angeles, New York, Pittsburgh, San Francisco • **CANADA:** Union Carbide Canada Limited, Toronto



Check your requirements against these
Wallace Barnes Cold-rolled Specialty Steels

Furnished in these carbon grades:

1.25 – 1.32% .90 – 1.05% .70 – .80% .59 – .74% .48 – .55%

ANNEALED AND HARD-ROLLED

Thickness

Thickness		Widths	Thickness		Widths
.003 – .010″	in widths	1/8 to 6 1/4″	.036 – .049″	in widths	3/8 to 13″
.011 – .014″	" "	3/16 to 11″	.050 – .064″	" "	1/2 to 13″
.015 – .019″	" "	3/16 to 13″	.065 – .093″	" "	3/4 to 6 1/4″
.020 – .035″	" "	1/4 to 13″	.093 – .125″	" "	3/4 to 6 1/4″

HARDENED AND TEMPERED

Scale-free or scaleless; polished*; polished and blued*; polished and strawed*

Thickness

Thickness		Widths	Thickness		Widths
.003 – .004″	in widths	1/8 to 2″	.031 – .035″	in widths	1/4 to 7″
.005 – .007″	" "	1/8 to 3″	.036 – .040″	" "	3/8 to 7″
.008 – .009″	" "	1/8 to 4″	.041 – .049″	" "	3/8 to 6″
.010 – .014″	" "	3/16 to 5″	.050 – .060″	" "	1/2 to 4″
.015 – .019″	" "	3/16 to 7″	.061 – .064″	" "	1/2 to 3″
.020 – .025″	" "	1/4 to 8 1/2″	.065 – .093″	" "	3/4 to 3″
.026 – .030″	" "	1/4 to 8″			

*Maximum width for polishing in .010 – .030 thickness ranges is 5 in.

Facilities for processing alloy steels also are available.

Standard sizes normally available for prompt shipments.

Write for a copy of "Physical Property Charts" that give performance characteristics of .90 – 1.05% and .70 – .80% carbon grades.

Wallace Barnes Steel Division

Bristol, Connecticut

Associated Spring Corporation

Now complex steel shapes, extruded in lengths up to fifty feet, make possible a radically different approach to metal fabrication techniques. The nominal limitations are that the design fit within a twenty-two inch circumscribing circle—have a minimum of five square inches in cross-sectional area.

This flexibility makes it possible to extrude complete units—eliminating many welding and machining operations. The result: *Genuine production savings.*

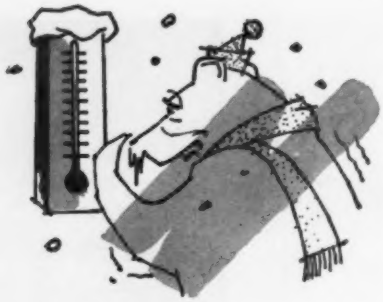
And the Curtiss-Wright extrusion process, using 24,000,000 pounds pressure, gives the metal non-directional physical properties—end-to-end uniformity—a fine internal finish. The result: *Substantially improved physical properties in the metal.*

Intricate extrusions can be made from all forgeable metals including ferritic or austenitic alloy steels, titanium and other special purpose materials.

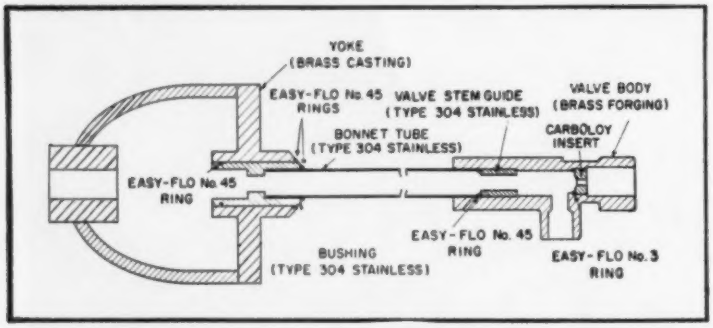
A twenty-four page brochure on CURMET custom extrusions has just been published. It presents the complete story on this exclusive method—tells how it can save time and money—how it achieves superior properties in the metals used. Write for it today.

CURTISS-WRIGHT CORPORATION **METALS PROCESSING** DIVISION
78 GRIDER STREET BUFFALO 15, NEW YORK

Don't Worry About Joint Strength
At Sub Zero Temperatures . . .



EVEN AT MINUS 300F HANDY & HARMAN SIL-FOS AND EASY-FLO BRAZED JOINTS ARE VERY STRONG



Six-Piece Expansion Valve Assembly For Air Separator Joined In One Operation: Drawing of valve assembly shows locations of 5 preplaced rings of EASY-FLO 3 and EASY-FLO 45.

The need for strong, tight joints for ultra cold service—in rocketry, cold treating and refrigeration of all types—becomes more and more critical.

Recent low temperature tests with Handy & Harman's silver brazing alloys SIL-FOS and EASY-FLO on deoxidized copper lap joints show impressive joint strength.

At minus 321°F, the joint strength (in psi) of EASY-FLO 45 is 30,100 lbs. At the same temperature, the psi of a SIL-FOS brazed joint is 21,900 lbs. These strengths represent the average of four tests with each alloy; HANDY FLUX was used in each test.

A current "sub-zero" example is Air Products, Inc., Allentown, Penn. This company makes an air separator which produces tonnage quantities of oxygen and/or nitrogen for industrial use. The separator's components consist of Type 304 stainless steel, cast bronze, brass, copper, copper bronze and Carboloy. Joint sizes range from less than ¼ inch to 54 inches in diameter. In operation the separator is exposed to temperatures of minus 300°F and pressures approaching 5000 psi. To join this complex assembly, Air Products uses Handy & Harman's EASY-FLO 35, EASY-FLO 3 and EASY-FLO 45 and HANDY FLUX.

Your NO. 1 Source of Supply and Authority on Brazing Alloys

HANDY & HARMAN QUALITY SERVICE

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OAKLAND, CALIF.
TORONTO, CANADA
MONTREAL, CANADA

FOR A GOOD START:
BULLETIN 20

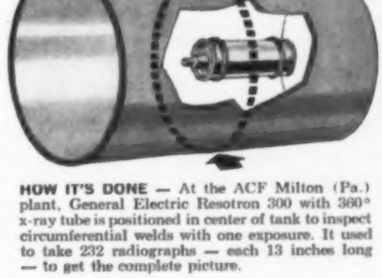
This concise bulletin introduces you to silver alloy brazing—gives joining methods and joint design as well as economies that exist with EASY-FLO brazing. Just ask, we'll be pleased to send you a copy.

Inspects circles around previous radiographic methods

G-E Resotron® 300 with 360° x-ray beam — makes one exposure do the work of 20!

That 24-foot strip of film they're holding represents *one* radiograph of a welded seam circling an American Car and Foundry Division tankcar. With almost 200 feet of welds to be inspected in each tank, full-circle x-ray technics with the G-E Resotron 300 have trimmed inspection costs to a shadow of their former selves. Moreover, exposure speed is ⅓ faster than any x-ray unit they tried before. And radiographs are better!

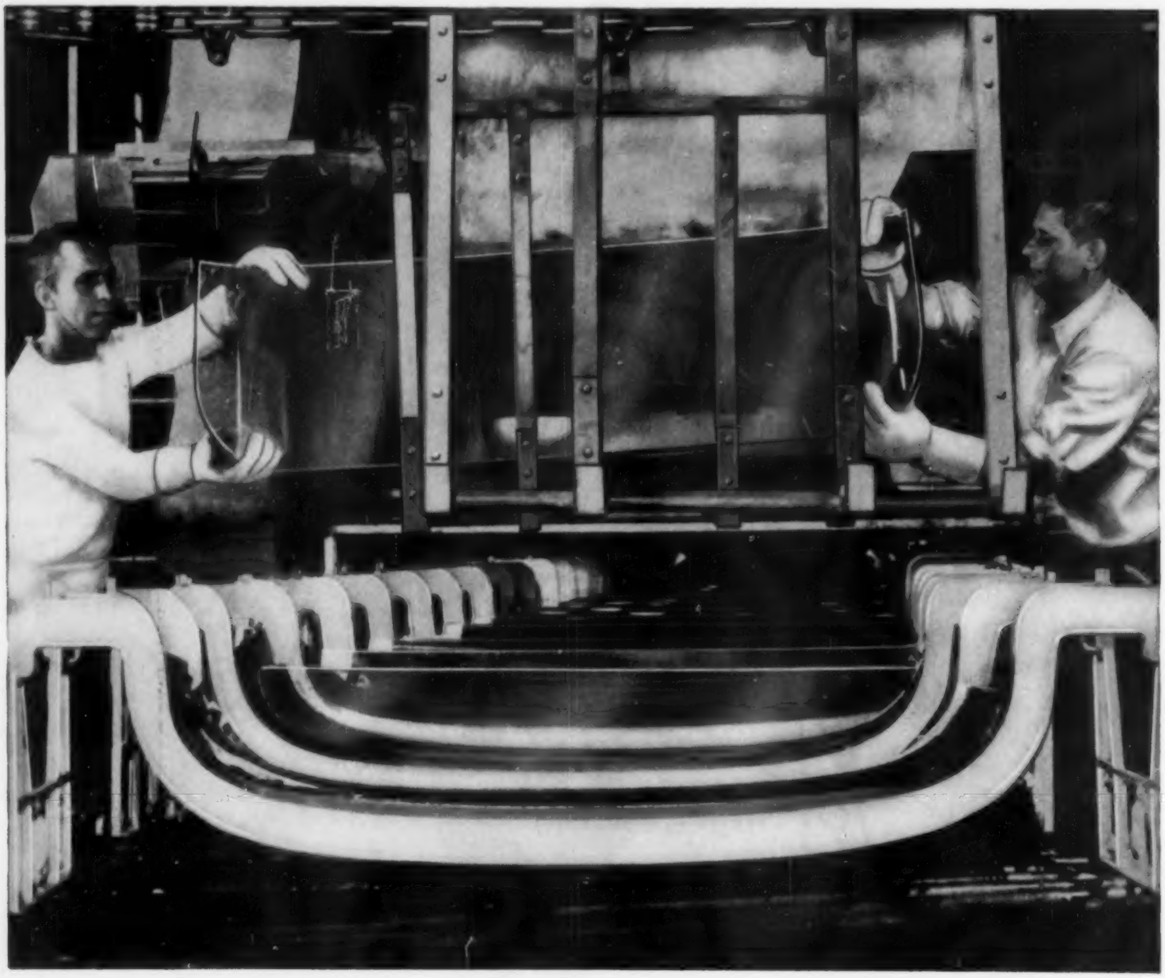
With big developments in x-ray equipment, film and processing, the speed of 100% radiographic inspection has come a long way lately. Your General Electric Representative has all the good news — call him in, or write X-Ray Department, General Electric Company, Milwaukee 1, Wisconsin, for Pub. AS-94.



HOW IT'S DONE — At the ACF Milton (Pa.) plant, General Electric Resotron 300 with 360° x-ray tube is positioned in center of tank to inspect circumferential welds with one exposure. It used to take 232 radiographs — each 13 inches long — to get the complete picture.

Progress Is Our Most Important Product

GENERAL ELECTRIC



Greater visibility, trimmer lines in new car styling... thanks to GAS

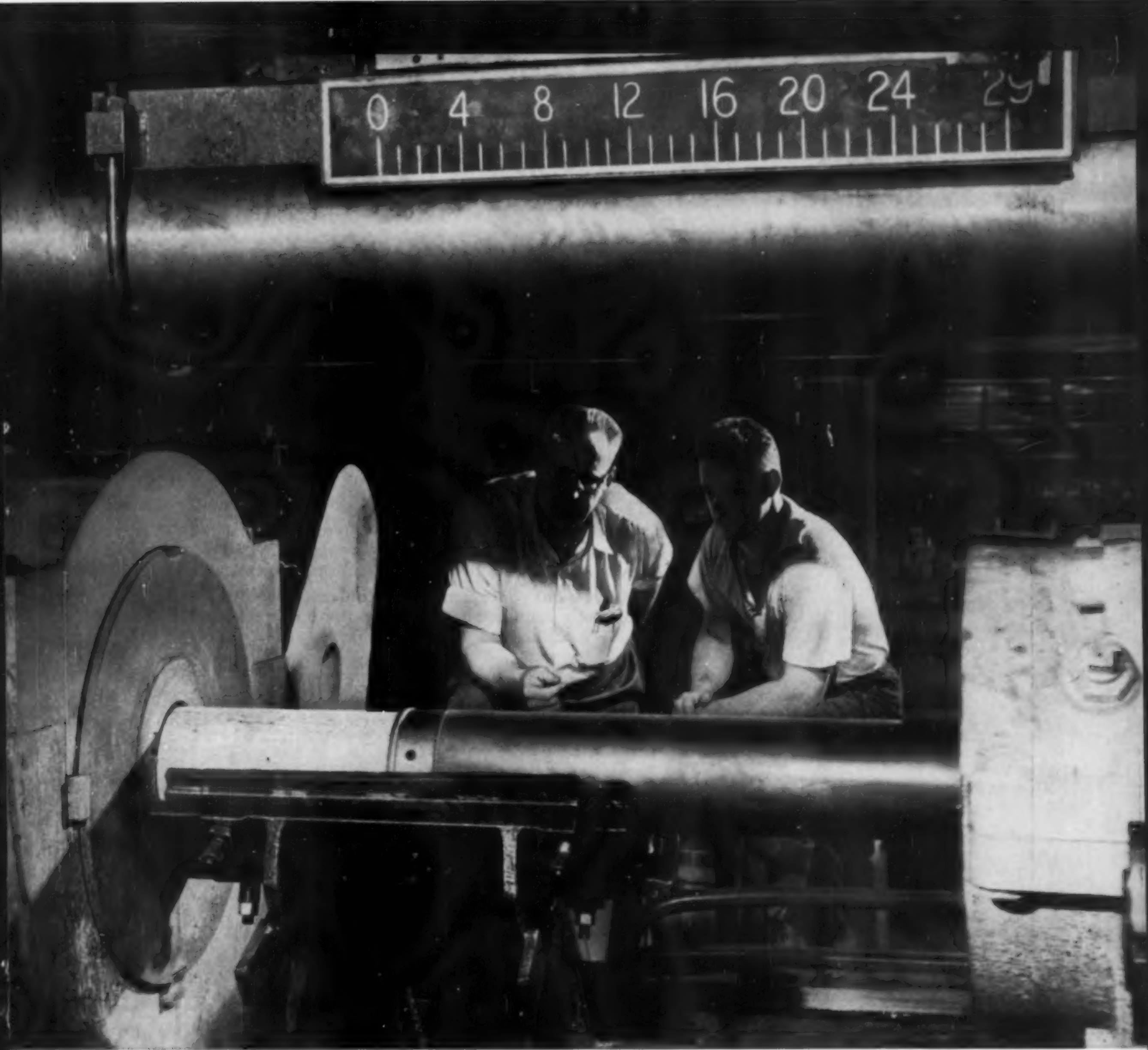
With nearly 7,000,000 cars being produced annually, the increased use of glass has demanded major production improvements in the manufacture of new panoramic windshields and back-lights.

Since the forming of the intricately curved glass is done at a temperature at which glass is soft and can be bent, the production process challenged heat process engineers to design new automatic equipment capable of mass producing these large precision glass pieces.

Selas engineers, working with the nation's leading glass manufacturer, discovered that Gas could produce the proper time-temperature cycle demanded by this process, efficiently, quickly, reliably. The flat glass is conveyed under radiant Gas burners which bring the glass quickly up to bending temperature and allow the shaping of windshields, with reproducible uniformity, at high production rates.

The production of this wrap-around windshield is another example of the contributions modern Gas equipment is making to American manufacturing. If you have an operation demanding precise process heating, call your local Gas Company's Industrial Specialist and discuss the economies and results you, too, can get with modern Gas equipment. *American Gas Association.*

See Playhouse 90 with Julia Meade on CBS-TV. Watch local listings for time and station. Sponsored by your Gas Company and the Gas Industry.



Why ALCAN extrusion ingot "runs" easier... faster... more economically!

How much difference would better quality billet make in your extruding costs and productivity? *A substantial difference* . . . if the billet you switch to is ALCAN!

For you will find that ALCAN billet offers you every fabricating advantage. It pushes easier, faster. It gives you longer die-life . . . less scrap . . . and better quality of finished product. All good reasons why a trial run can prove to you that this is the most economical billet you can use!

From mining to casting—countless checks on quality make ALCAN the finest of all billet products. It is made entirely of clean, primary metal . . . unexcelled in internal structure and surface smoothness . . . and cast to the industry's closest tolerances.

Telephone us today about testing ALCAN billet on your own equipment! We welcome the opportunity to show you the difference it can make in your extruding costs and productivity.

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Additional distribution (Alcan Foundry Alloys):
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Charles Batchelder Co., Inc., Botsford, Conn.

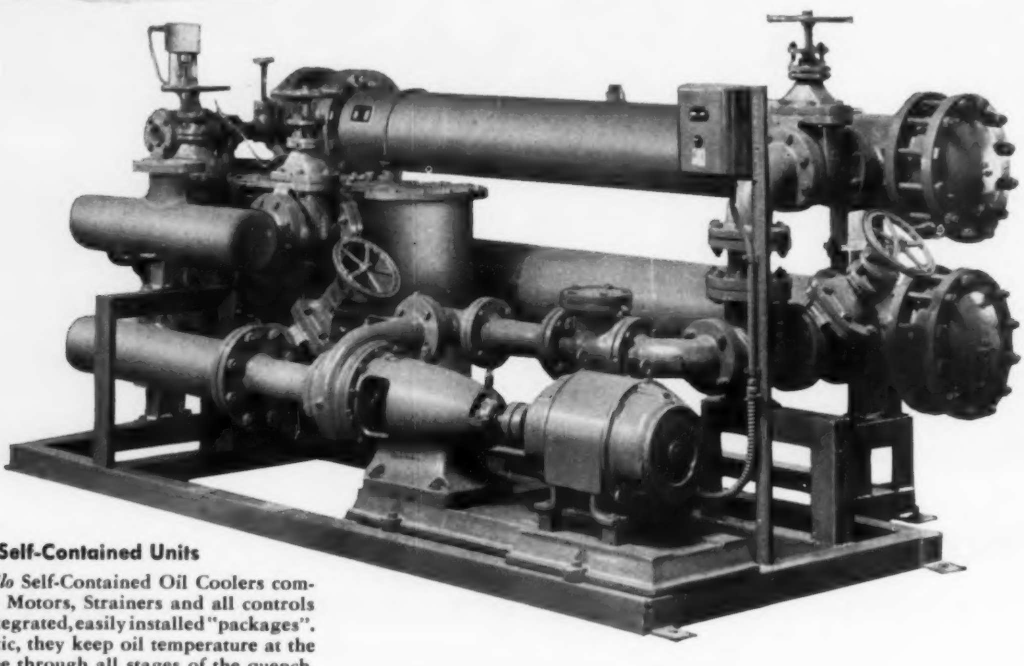
HOW MUCH IS *Faulty Quenching* COSTING YOU?

The quenching stage of your heat-treating process is the point which determines . . . (1) the final quality of your product . . . (2) the amount of time and material wasted by below-standard rejects . . . and (3) your ultimate operating costs.

You can protect yourself against needless production losses by installing a B & G Self-Contained *Hydro-Flo* Oil Cooler. This unit will provide the accurate control of conditions in the quench tank which assures *uniform quality* in the finished product.

The generous heat transfer surface in B & G Self-Contained *Hydro-Flo* Oil Coolers provides large capacities in comparatively small, compact units. They are completely factory assembled, ready for immediate installation and operation.

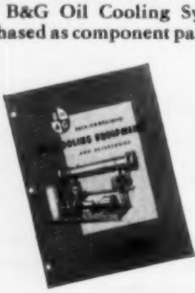
Tell us about your quenching problems—we'll be glad to offer engineering counsel and recommendations.



Completely Self-Contained Units

B&G *Hydro-Flo* Self-Contained Oil Coolers combine Coolers, Motors, Strainers and all controls into single, integrated, easily installed "packages". Fully automatic, they keep oil temperature at the desired degree through all stages of the quench. Your only responsibility is to connect to the quench tank and water lines.

B&G Oil Cooling Systems may also be purchased as component parts for assembly on the job.



This combined Catalog and Selection Manual gives full information on B&G Self-Contained Oil Coolers. Send for your copy.

B & G

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Hydro-Flo

OIL QUENCHING SYSTEMS

BELL & GOSSETT COMPANY

Dept. FW-16, Morton Grove, Illinois

Canadian Licensee: S. A. Armstrong Ltd., 1400 O'Connor Drive, Toronto 16

At arctic temperatures and supersonic speeds

...what happens to aircraft skin?

Technicians of Aircraft X-ray Labs, Huntington Park, Calif., radiograph fin of aircraft at –65°F

WITH AIRCRAFT POWER mounting, with speeds that leave sound behind, extremely high frequency vibrations were bound to build up. What would be their effect on aircraft structures—at temperatures ranging to 65°F below zero? To find out, radiography and Kodak Industrial X-ray Film, Type AA, were put to work.

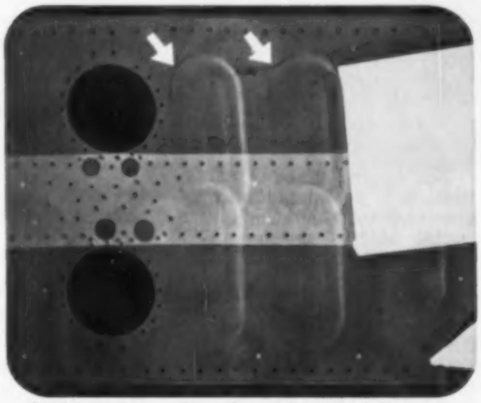
The radiographs revealed fatigue failures and gave clues to the nature of the stresses.

Exposures were made at target distances from 5′ to 15′ with exposures from 40 sec. to 90 sec. In spite of the cold, the film received no special handling.

All of which shows the importance of radiography as a test—also the dependability and versatility of Type AA Film.

If you build intricate assemblies, make castings or produce welded products, radiography can provide inside information as nothing else can. It can save time and money—improve foundry production and welding operations.

If you would like to know how it can help you, discuss it with your Kodak x-ray dealer—or with the Kodak Technical representative.



Radiograph reveals evidence of material fatigue under stress.

X-ray Division . . . EASTMAN KODAK COMPANY. . . Rochester 4, N. Y.

Read what Kodak Industrial X-ray Film, Type AA, does for you:

- Speeds up radiographic examinations.
- Gives high subject contrast, increased detail and easy readability at all energy ranges.
- Provides excellent uniformity.
- Reduces the possibility of pressure desensitization under shop conditions.

Kodak

The 14th METALLOGRAPHIC EXHIBIT

Chicago, November 1 to 6, 1959

All metallographers—
everywhere—
are cordially invited to
display their best work.

RULES FOR ENTRANTS

Exhibitors do not need to be members of the American Society for Metals.

Work which has appeared in previous metallographic exhibits held by the American Society for Metals is unacceptable.

Photographic prints should be mounted on stiff cardboard, extending no more than 3 in. beyond edge of print in any direction; maximum dimensions 14 by 18 in. (35 by 45 cm.). Heavy, solid frames are unacceptable.

Entries should carry a label on the *face of the mount* giving:

Classification of entry.

Material, etchant, magnification.

Any special information as desired.

The name, company affiliation and postal address of the exhibitor should be placed on the *back of the mount* together with a request for return of the exhibit if so desired.

Entrants living outside the United States should send their micros by first-class letter mail endorsed "Photo for Exhibition—May Be Opened for Customs Inspection".

Exhibits must be delivered before Oct. 15, 1959, either by prepaid express, registered parcel post or first-class letter mail, addressed:

Metallographic Exhibit
American Society for Metals
53 W. Jackson Blvd.
Chicago 4, Ill., U.S.A.

CLASSIFICATION OF MICROS

Class 1. Cast irons and steels.

Class 2. Carbon and alloy steels (wrought).

Class 3. Stainless steels and heat resisting alloys.

Class 4. Aluminum, magnesium, beryllium, titanium and their alloys.

Class 5. Copper, nickel, zinc, lead and their alloys.

Class 6. Uranium, plutonium, thorium, zirconium and reactor fuel and control elements.

Class 7. Metals and alloys not otherwise classified.

Class 8. Series showing transitions or changes during processing.

Class 9. Welds and other joining methods.

Class 10. Surface coatings and surface phenomena.

Class 11. Slags, inclusions, refractories, cermets and aggregates.

Class 12. Electron micrographs.

Class 13. Results by unconventional techniques.

Class 14. Color prints in any of the above classes. (No transparencies accepted.)

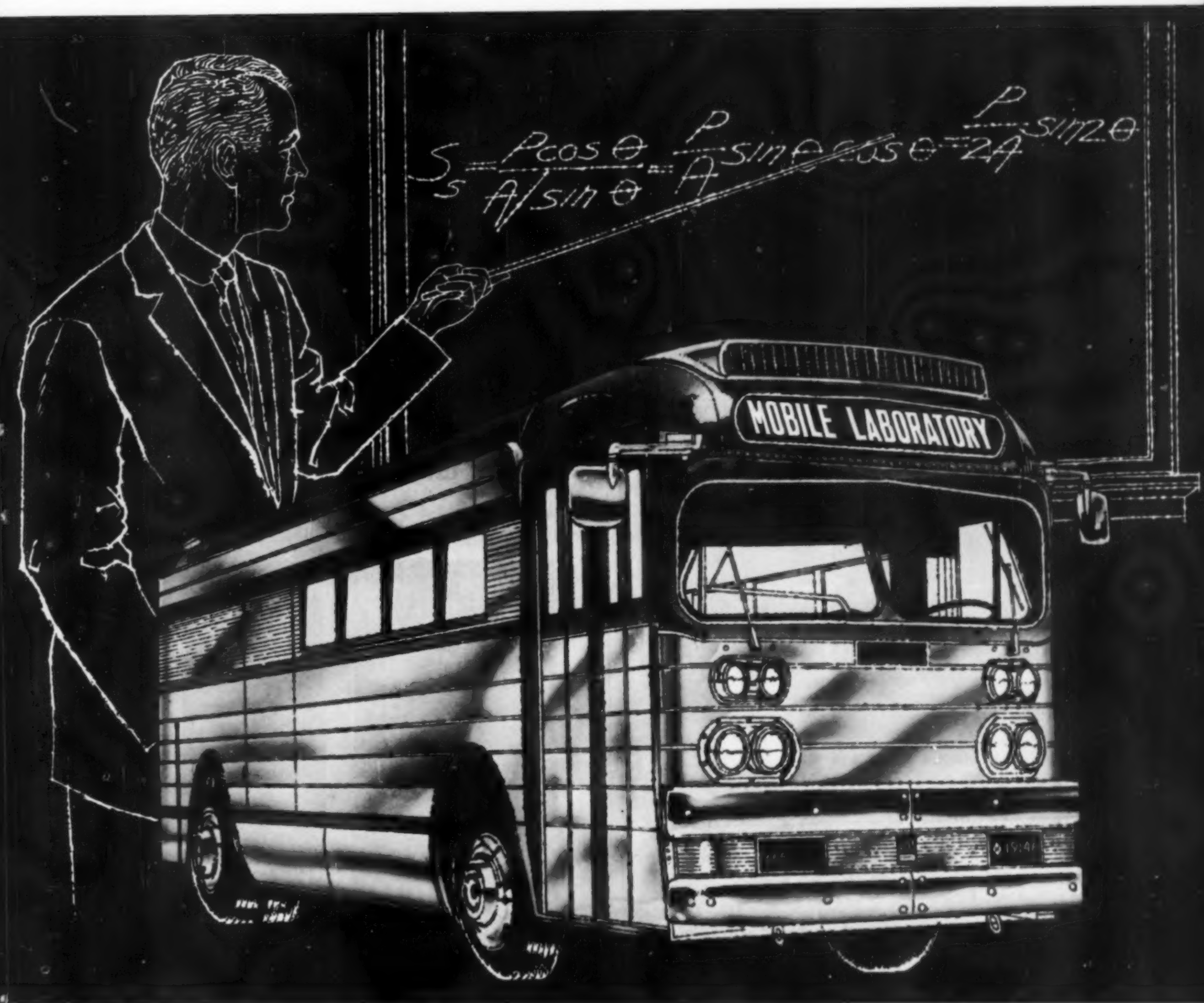
AWARDS AND OTHER INFORMATION

A committee of judges will be appointed by the Metal Congress management which will award a First Prize (a medal and blue ribbon) to the best in each classification. Honorable Mentions will also be awarded (with appropriate medals) to other photographs which in the opinion of the judges closely approach the winner in excellence. A Grand Prize, in the form of an engrossed certificate and a money award of $500 from the Adolph I. Buehler Endowment will also be awarded the exhibitor whose work is judged best in the show, and his exhibit shall become the property of the American Society for Metals for preservation and display in the Society's national headquarters.

All prize-winning photographs will be retained by the Society for one year and placed in a traveling exhibit to the various ASM Chapters.

41st NATIONAL METAL CONGRESS & EXPOSITION

INTERNATIONAL AUDITORIUM — — — CHICAGO — — — NOV. 1 to 6, 1959

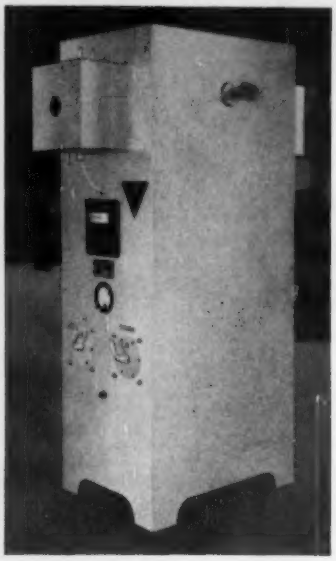

$S_s = \frac{P\cos\theta}{A/\sin\theta} = \frac{P}{A}\sin\theta\cos\theta = \frac{P}{2A}\sin 2\theta$
MOBILE LABORATORY

PERECO

ELECTRIC TUBE FURNACES

for LABORATORY WORK

requiring close control of temperatures to 2800° F.



- **Tubular globar heating elements in lengths up to 60 inches (12" I.D. Max.)**
- **Water-cooled terminals**
- **Precision temperature controls for wide range control and turndown**
- **Designed for either normal or extremely rapid heat-up**
- **Cabinet or trunion mounted horizontal to vertical (90°) swing.**

Tubular Silicon-Carbide Elements—Cabinet or Trunion Mounted

Pereco Electric Tube Furnaces are available with many modifications for meeting individual types of investigations or laboratory control and process work. Units illustrated above incorporate hollow silicon-carbide heating elements (2" I.D.) that can be any length, in 2" increments, up to 60". For work requiring larger tube dimensions, units can be furnished utilizing a ceramic tube surrounded by a number of solid ("AT"-type) silicon-carbide heating elements with air-cooled terminals. To quickly determine if a Pereco Tube Furnace might be "your better answer" tell us about your work requirements. No obligation.

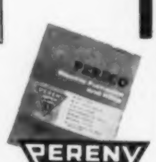
Upper Left:— Model MT 30 x 2

Above:— Model MT 30 x 2-T

NOW AVAILABLE

Kanthal-Super Element equipped Pereco Furnaces & Kilns for continuous operation up to 2950° F. in oxidizing atmospheres. Write today for details.

Write Today for Get-acquainted Bulletin



STANDARD or SPECIAL Furnaces or Kilns from 450° F. to 5000° F.

PERENY EQUIPMENT CO.

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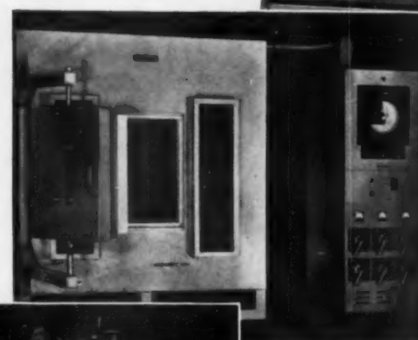
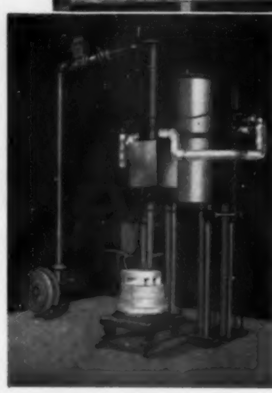
HARROP serves research and manufacturing with standard and special furnaces

Electric — MR Series, Metallic Resistors; radiation or convection heating



Electric — NMR Series, Non-Metallic Resistors; cabinet, box, tube, elevator types

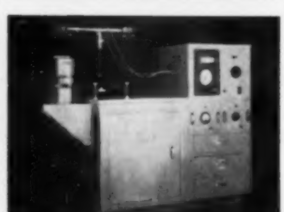
Gas-Fired — floor or elevator types



When you require *controlled* application of heat . . . in research, testing or small-parts manufacturing . . . Harrop experience can guide you to the selection of the most serviceable furnace. Chances are there's a *standard* Harrop model that will meet your needs. But it's routine for Harrop to equip a standard furnace with almost any combination of *special instrumentation* for exacting specific procedures. And the first-time-ever assignment is readily undertaken by its design engineers and production experts.

To suggest the scope of Harrop's experience and ability to serve your requirements for the precision *controlled* application of heat:

Firing — electric or gas
Temperatures — up to 4,200° F. (and higher if required), in controlled atmospheres
Instrumentation — for any need, both in respect to control and to control forms affecting the time-temperature-atmosphere relations
Setting Space — in diverse form to meet specific need, in shape and size and in mechanical and electrical accessories



Representative of Harrop ability to do the unusual is this interferometer.

For Non-Obligating Recommendations, send information on materials, temperature range, heat control and firing objectives to Dr. Robert A. Schoenlaub, Technical Director.

HARROP ELECTRIC FURNACE DIVISION
of Harrop Ceramic Service Co.
Dept. M 3470 E. Fifth Ave. Columbus 19, Ohio

Behind the By-lines

D. J. Schmatz, J. C. Shyne and V. F. Zackey, who discuss the new "Ausform" process for improving steel by austenitic cold working on p. 66 of this issue, report that the most common question asked about this process is, "How can it be used in automobiles?" – a natural question, since this process was developed at Ford Motor Co.'s Scientific Laboratory. While not usually concerned with specific applications of metallurgical products, the three authors have spent some pleasant hours cooking up an "indestructible" automobile, fabricated from Ausformed ultra-high-strength steel – ideal for rush-hour traffic, beginning drivers and wives with fender-scraping tendencies.

Dr. Zackey, as supervisor of the physical metallurgy section, has the administrative and research responsibilities for both basic and long-range applied programs. His research activity encompasses varied fields including studies in thermodynamics and phase transformation. Dr. Shyne, an experimental physical metallurgist, has been engaged on research in the development of ultra-high-strength steels and studies on strain aging characteristics of steels. Mr. Schmatz, the most recent addition of the three to Ford's laboratory, joined the company with a background in phase deformation and diffusion in steels and alloys.

Clark E. Quinn, whose work on the Laminagage for nondestructive testing of metals using eddy currents resulted in the article on p. 70, is pictured below with Joe Felice in the General Motors Research Laboratories mulling over a problem connected with the recently publicized G.M. Highway Information System – an electronic communication system to improve highway safety. Called the Hy-Com, the system will transmit traffic bulletins to automobiles moving along the highway within its range. A transmitter operating at short range (a distance of some 100 ft. – enough for a four-lane highway) will transmit messages to a receiver con-

C. E. Quinn (right) in the G.M. research laboratory

nected to a standard car radio. According to Mr. Quinn, the system can serve varied purposes – from warning of hazardous road conditions ahead to announcing the next service station.

In the 17 years he has been associated with General Motors Research Laboratories, designing and developing special electrical and electronic circuitry and instrumentation, Mr. Quinn has worked on a number of important projects, including development of the Sonigage, the electrical system for Firebirds 1 and 2, and many, many others.

H. W. Schultze (author of the article on vapor-phase plating on p. 74), originally a teacher of analytical and general chemistry at Rensselaer Polytechnic Institute, moved into industry to satisfy his desire to probe the practical side of the new technologies being developed. Since joining Climax Molybdenum Co. in 1956, he has been conducting research to find new applications for molybdenum and tungsten compounds, and through his work on vapor-phase deposition, was instrumental in making some of these products readily available. He describes the possibilities for molybdenum and tungsten chemicals as "virtually unlimited and a great challenge to uncover".

Harry Jackson's avid interest in golf *may* be just one of the reasons why *Metal Progress* is publishing this month (p. 89) the last article of a three-part series on forging, written by Dr. Jackson and his Battelle colleague, Harry Goodwin. The articles are an expansion of a talk he presented before the 1958 annual meeting of the Drop Forging Association, and the meeting was held, coincidentally, just an iron shot away from the championship golf course at the Homestead in Hot Springs, Va.

However, Dr. Jackson's reputation as a golfer is even surpassed by his reputation as an expert on research on metalworking and metallurgical problems. With Harry Goodwin's able collaboration, the resultant three articles have provided our readers with a survey of forging in the past, present and its role in the future.

Both Dr. Jackson and Mr. Goodwin are vitally concerned with the entire spectrum of work being done in the Battelle laboratories (currently some 270 projects) but they have retained a few special interests from their laboratory bench days. Some of Harry Jackson's particular interests are foundry practice, titanium alloys and stainless steel, while Harry Goodwin follows the developments in refractory metals, high-purity metals, brittle fracture and metal fibers.

The comprehensive report on oxygen in steelmaking on p. 101 was compiled by E. C. (Chet) Wright after a 14-day tour of steelmaking plants in the United States and Canada. The result, after a thorough sifting of all the facts he'd collected, was the leadoff article of our section on Steelmaking on the Move – a pertinent report giving a survey of oxygen steelmaking. Chet, a consulting editor for *Metal Progress*, is head of the department of metallurgical engineering at the University of Alabama, but before his teaching days, he was assistant to the president of the National Tube Div. of U. S. Steel Corp.

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